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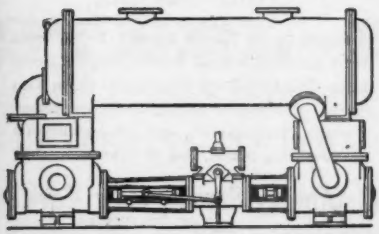

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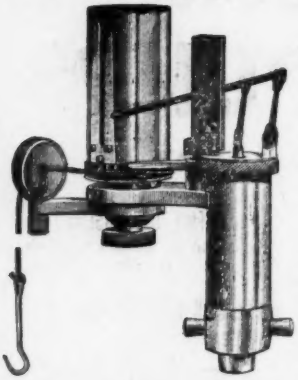

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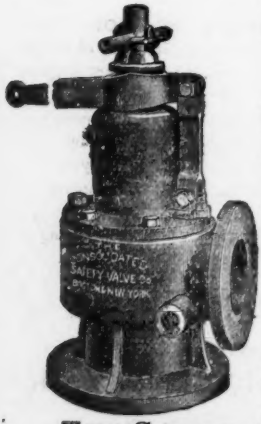

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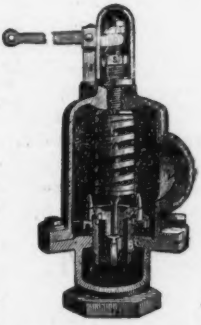

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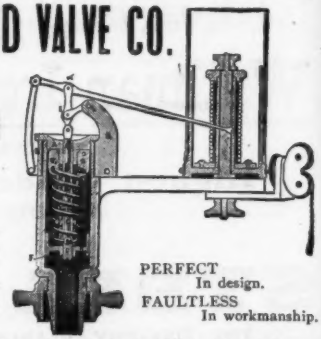

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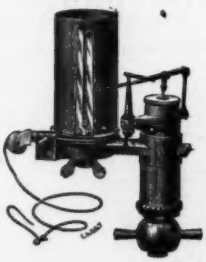

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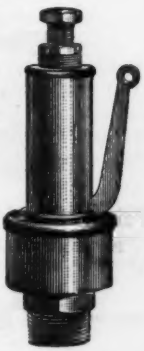

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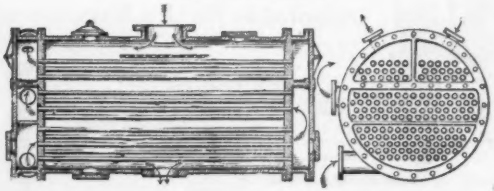

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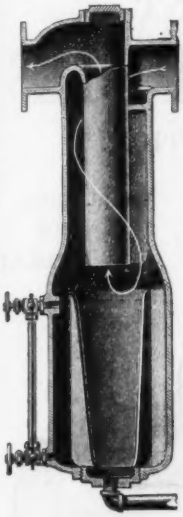

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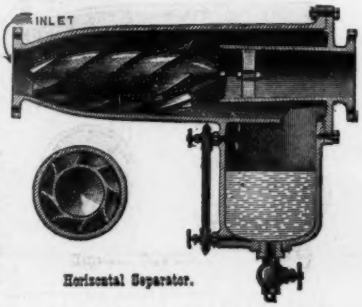

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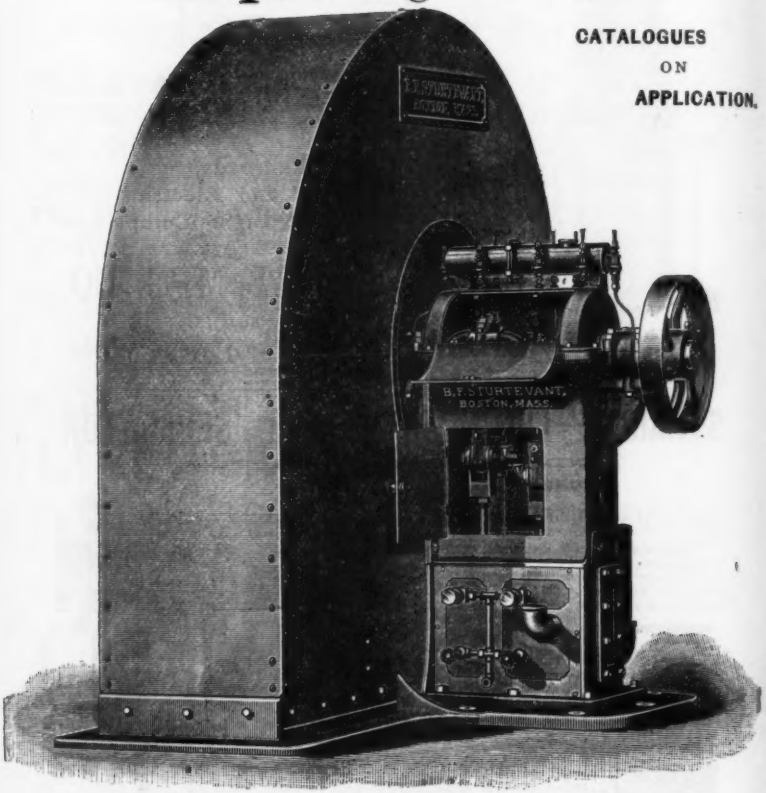

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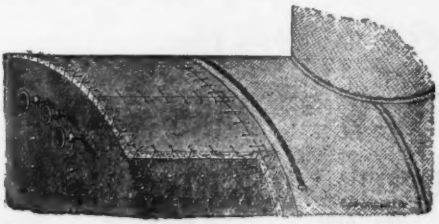

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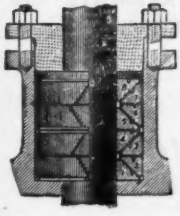

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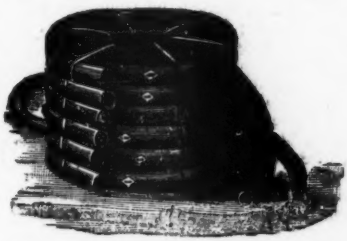

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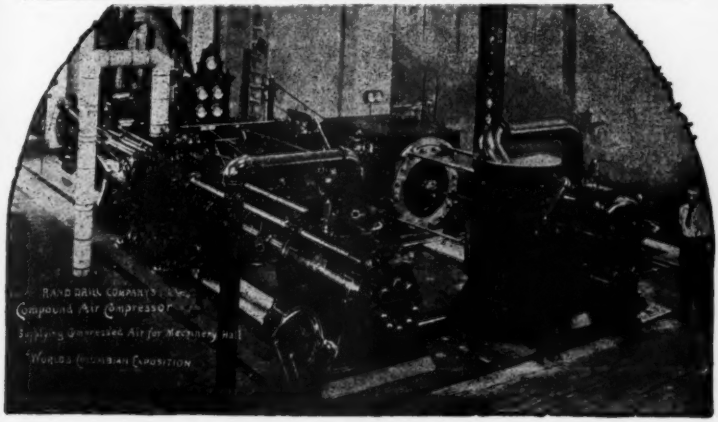

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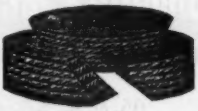

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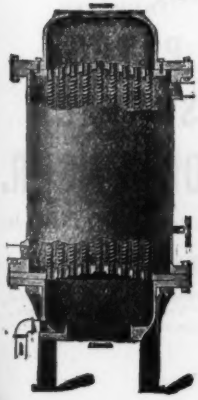

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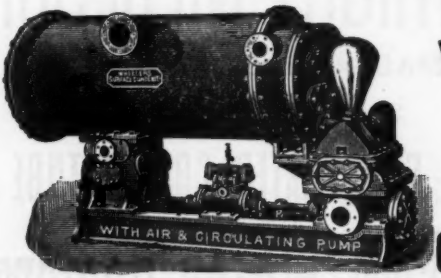

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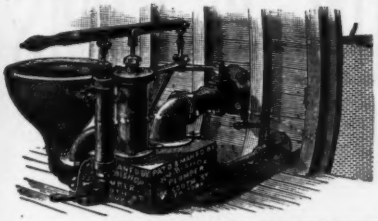

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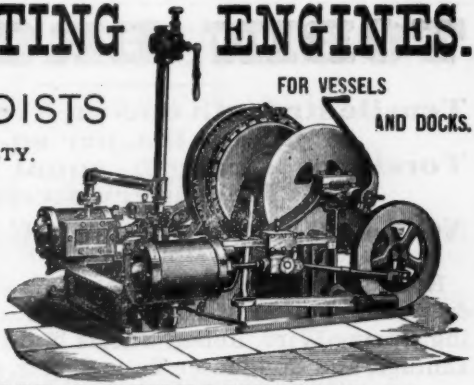

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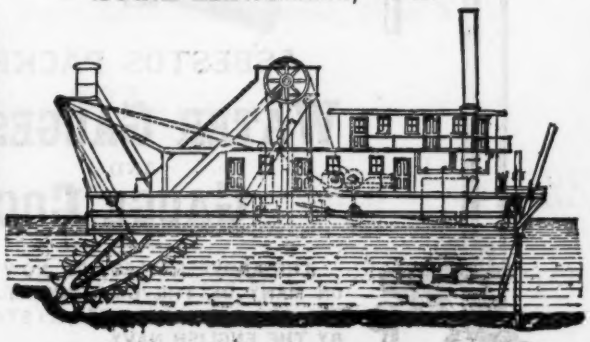

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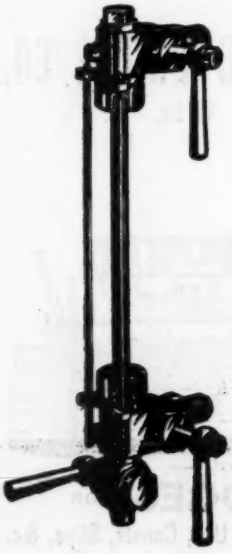

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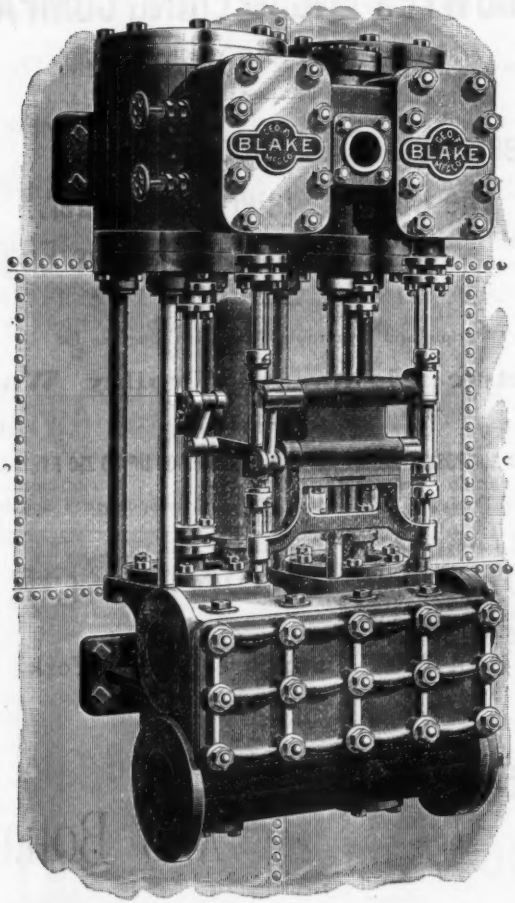

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ON THE ANALYSIS OF CERTAIN CURVES ARISING IN ENGINEERING INVESTIGATIONS.

BY PROFESSOR WM. F. DURAND, OF CORNELL UNIVERSITY.

These curves may be considered algebraically to be of the form

$$y = Bx^n.$$

Equations of this form frequently arise where it is sought to express the relation between some result y, a uniformly varying quantity x, and some constant or slowly varying quantity B.

The latter quantity, B, may involve several other quantities in a more or less obscure fashion, as will appear from the instances given.

As examples of this equation we may consider y as resistance, x as speed, and B as involving the elements of form, size and quality of surface. The equation as a whole, then, represents the resistance of a body moving at variable speed through a liquid. Or again in an equation of the same form y may represent power, either effective or indicated. As a further example, we may

take the form of expansion curve for the working substance in a heat engine, the equation to which is usually considered of the form:

$$pv^n = C, \text{ a constant.}$$

This is equivalent to $p = Cv^{-n}$, an equation in the form noted.

Still other instances drawn from other fields of engineering will readily suggest themselves.

(2) Taking, now, the equation in form as stated we have:

$$y = Bx^n, \tag{1}$$

whence

$$\log y = \log B + n \log x, \tag{2}$$

Considering all quantities in the second member as variables, we have

$$\frac{dy}{dx} = x^n \frac{dB}{dx} + Bnx^{n-1} + Bx^n \log x \frac{dn}{dx}, \tag{3}$$

Dividing (1) by x we have

$$\frac{y}{x} = Bx^{n-1}, \tag{4}$$

Dividing (3) by (4), we have:

$$\frac{dy}{dx} \div \frac{y}{x} = \frac{x}{B}\frac{dB}{dx} + n + x \log x \frac{dn}{dx}, \tag{5}$$

(3) We will next examine the meaning of the assumption that B, x and n are all variable, B and n being unknown.

Referring to (1), it is readily seen that for any assigned value of B, a possible value of n will result, and vice versa for any assigned value of n, a possible value of B will result. It follows, therefore, that this assumption involves a wholly indeterminate series of values for B and n, or in other words, that there are an infinite number of pairs of values of B and n corresponding to any given value of y. The result is therefore in such case, without further conditions, a wholly meaningless equation.

(4) Suppose that B is taken as a constant but is unknown, while n may be variable and is likewise unknown. It is readily seen in this case, as in the last, that for any constant value of B, a possible series of values for n will result. Therefore since B is supposed to have some one constant value, it is evident that

corresponding to this there will be some one definite series of values for n.

If in (2) we make $x = 1$ we have $y = B$.

That is, in such a case, B will equal the value of y, for x equal 1.

The value of n results directly as

$$n = \frac{\log y - \log B}{\log x} = \frac{\log y - \log y]_1}{\log x}, \qquad (6)$$

(5) Suppose next that B is supposed constant and known. There will immediately result a definite value or series of values for n given by proper substitution in (6) above.

(6) We next assume n constant and unknown, B being variable and also unknown. In this case any constant value of n will give a corresponding value or series of values of B, and therefore there will be for the given value of n a definite value or series of values of B. It does not appear possible however, in this case, to find the value of n and from it the value or values of B. The difference between this case and that of (3) arises from the fact that in the former it is possible to give such a value to x as to cause n to disappear from equation (2), thus allowing of a determination of B. In the present case, B cannot be made similarly to disappear, and therefore we cannot determine the value of n. It therefore appears that this case is similar to that noted in paragraph (3), and hence that the equation under such suppositions is wholly indefinite.

(7) We suppose next that B and n are both constant but unknown. In this case each quantity will have but a single definite value. Equation (5) gives for this case:

$$\frac{dy}{dx} \div \frac{y}{x} = n. \qquad (7)$$

We thus determine n and thence B by substitution in equation (2).

(8) If B and n are both constant and either is known or assumed, the other readily follows from (2).

(9) We now turn to another phase of the question. This involves the definition of an index m, such that at a certain point we may say that y varies as the m'th power of x. To make the question specific, we may ask as to just what is meant by

the statement that at a certain speed the I.H.P. varies as the 3d power of the speed, while at a different speed we may say that the variation is as the power 3.5 or 4 or m. The plain meaning of the phrase is, that at such given point the power is increasing at such rate that if the speed is multiplied by e, the power must be multiplied by e^3, or $e^{3.5}$, or e^m, this rate of variation being assumed to hold constant between the two speeds in question. Suppose e to be of the form $(1 + c)$ where c is a very small quantity. The two speeds will then be separated by a very small interval. Call v_1 the given speed, and H_1 the corresponding power. Then $v_1 (1 + c) = v_2$ the second speed, and $v_1 c$ equals the increase of speed. Also $H_1 (1 + c)^m = H_2$ the new power. Now since c is very small, we may neglect powers higher than the first. This gives $H_2 = H_1 + mcH_1$, and therefore the increase of power is mcH_1. The increase of power divided by the increase of speed equals $m \frac{H_1}{v_1}$, and therefore

$$m = \frac{\text{ratio of increase of H to increase of } v}{\text{ratio of H to } v}, \tag{8}$$

Or in other form

$$m = \frac{\text{ratio of increase of } H_1 \text{ to H}}{\text{ratio of increase of } v_1 \text{ to } v}. \tag{9}$$

Another way of considering m, which comes to the same thing, is to consider it as the exponent of x in an equation, $y = Bx^m$ where B is constant and m is taken as practically constant for a short distance on either side of the point in question. Suppose x_1 to define this point, and x_0, x_2 to define two points, one on either side. Then assuming between these limits, constant values of B and m we have:

$$y_0 = Bx_0^m \text{ and } y_2 = Bx_2^m.$$

Whence

$$\frac{y_2}{y_0} = \left(\frac{x_2}{x_0}\right)^m \text{ and } m = \frac{\log y_2 - \log y_0}{\log x_2 - \log x_0}. \tag{10}$$

This will evidently give for m, a mean value between x_0 and x_2, and the value will be the more accurate, the smaller the interval. To show that the index m as defined by this equation,

involves the same fundamental idea as that in the m as previously defined, we pass to the limit in the present case and find $m = \frac{d(\log y)}{d(\log x)}$.

Whence

$$m = \frac{dy}{y} \div \frac{dx}{x} = \frac{xdy}{ydx} = \frac{dy}{dx} \div \frac{y}{x}. \qquad (11)$$

We then take the form resulting from the first definition of m, and passing to the limit in the same way we have:

$$m = \frac{d\mathrm{H}}{dv} \div \frac{\mathrm{H}}{v} = \frac{d\mathrm{H}}{\mathrm{H}} \div \frac{dv}{v}. \qquad (12)$$

The two values of m in equations (11) and (12), are readily seen to be identical in character.

We may reach the value of m, in equation (11), more readily from equation (5), by making B and n constant. The value in (11) then immediately results from (5).

(10) We wish to note clearly at this point, that in paragraphs (1) to (8), inclusive, we have been concerned with the definition of a certain exponent n, and with the developement of various equations showing its relation to the other quantities involved. In paragraph (9) we have defined another index m, and have derived various expressions for its value in equations (8), (9), (10) and (11). We have now to compare these two exponents, m and n, and to establish such relationships as may exist between them.

From equation (5) we have:

$$n = \frac{dy}{dx} \div \frac{y}{x} - \left[\frac{x}{\mathrm{B}} \frac{d\mathrm{B}}{dx} + x \log x \frac{dn}{dx}\right] \qquad (13)$$

while

$$m = \frac{dy}{dx} \div \frac{y}{x}. \qquad (14)$$

The difference between the two is therefore the term in parenthesis. Although at first sight it might have been expected that the two exponents as defined, would result in all cases identical, yet it appears that such is by no means the case. In other words, the exponent m, can by no means be used in general for the exponent of x, in an equation $y = \mathrm{B}x^n$, intended as a general expres-

sion of the value of y, in terms of x. Vice versa, it appears that if we have the values of n for such a general expression, it by no means follows that we can, at any particular point, consider y as varying with the n'th power of x.

In order that m and n may be identical, the term in the parenthesis must vanish. This may result in either of two ways:

(1) Both B and n may be constant.

$$(2)\quad \frac{x}{\mathrm{B}}\frac{d\mathrm{B}}{dx} = -x \log x \frac{dn}{dx}. \qquad (15)$$

It follows, therefore, that if both B and n are absolutely constant, the exponents m and n are identical, and any method which will give one will likewise give the other. In the general case, however, and in fact in the cases which are usually met with in practice, B and n are not both constant.

(11) Suppose now that nothing is known regarding the nature of the variation of either B or n. Let values of y corresponding to known values of x be given; that is, let the data for a curve between y and x be known. From this, m may be determined. If m results a constant, such is also the constant value of n, the two being in this case identical. In general, however, m will not result a constant; but since n is wholly indeterminate, it is evident that the series of values of m is also a possible series of values of n, and that to such values of n there will correspond a series of values of B. The differential equation connecting these series of values of B and n is evidently given by putting the parenthesis in (13) equal to 0. This gives the condition expressed in (15). This equation together with the fundamental would serve to determine, in connection with the resulting series of n, a certain definite series of values of B, the two being so related as to fulfil both the fundamental and the differential equations. If these series of values of B and n are put in the fundamental equation, it is evident that the series of values of y would correctly result; that is, in this case, the values of m not only give the index of variation of y with x, but serve also as exponents in the general equation, the values of B having been correspondingly determined.

(12) The significance of the particular series m when used as exponents in the general equation may be further illustrated as follows:

Let corresponding values at any point be m_1 and B_1. Then consider the curve $y = B_1 x^{m_1}$. At the given point it will be coincident with the given curve considered as represented by the general equation $y = Bx^n$. From these we have respectively,

$$\frac{dy}{dx} = B_1 m_1 x^{m_1 - 1} \tag{16}$$

and

$$\frac{dy}{dx} = Bnx^{n-1} + x^n \frac{dB}{dx} + Bx^n \log x \frac{dn}{dx}. \tag{17}$$

But at this point we have

$$\frac{dB}{Bdx} + \log x \frac{dn}{dx} = 0, \; n = m_1 \text{ and } B = B_1,$$

Whence

$$\frac{dy}{dx} = B_1 m_1 x^{m_1 - 1} = Bnx^{n-1}.$$

Hence at this point the two curves not only meet, but have the same direction as well. It appears, therefore, that the values m_1 and B_1 for any particular point used as the exponent and coefficient in the general equation, will determine a curve identical at such point with the given curve in location and direction. This then is the particular additional condition fulfilled by the series of values m when used as one of the possible series for n in the general equation.

(13) Suppose next that B is taken as constant but unknown, while n is variable and unknown as in section (4). This case is one of the most important practically with which we shall meet. Suppose, for example, we fix our attention on the resistance of a ship at varying speed. So long as the speed alone changes, all questions of the geometry of form, quality of surface, etc., remain constant, speed being the only variable. In an equation $R = Bv^n$, considered to represent such case, we must therefore understand B as simply involving quantities which relate to the ship, and which are therefore constant in this case. The value of n under

such circumstances is given in section (4). Another value more appropriate to our present purposes, however, may be derived from equation (5) by making $\frac{dB}{dx}$ constant.

We thus find

$$n = \frac{dy}{dx} \div \frac{y}{x} - x \log x \frac{dn}{dx}. \tag{18}$$

The first term of the right hand member we have seen to be equal to m. We have therefore,

$$m = n + x \log x \frac{dn}{dx}. \tag{19}$$

Now, in general, in such cases, n is not constant, and, therefore, m does not and cannot equal n. It follows that in this case the values m cannot be used for n in the general equation, or if they are so used the corresponding values of B will not be constant, and the fundamental conditions will be violated. The corresponding values of B would, in fact, follow such law that the differential equation (15) would be satisfied.

To illustrate this point, take the formula:

$$\text{I.H.P.} = \frac{D^{\frac{2}{3}}V^n}{K}, \tag{20}$$

where $\frac{D^{\frac{2}{3}}}{K}$ represents quantities depending on the ship. If now we have a speed curve for such a case, we may evidently find values of m and may say that at such and such speeds the power varies as the exponent 3, 3.5, or 4 of the speed. These values, however, cannot be put as exponents into a general equation of the form assumed, and if they were taken as such exponents, the value of $\frac{D^{\frac{2}{3}}}{K}$ would be found to be a variable instead of a constant. *Vice versa* if the values of n were correctly determined for various points, we could not say that at these points the work varied as such powers of the speed. We wish thus to emphasize the fact that these two exponents, as defined, are, in general, not the same, and cannot be used one for the other. We have already seen in section (4) how n is to be determined under the circumstances assumed in this case. We

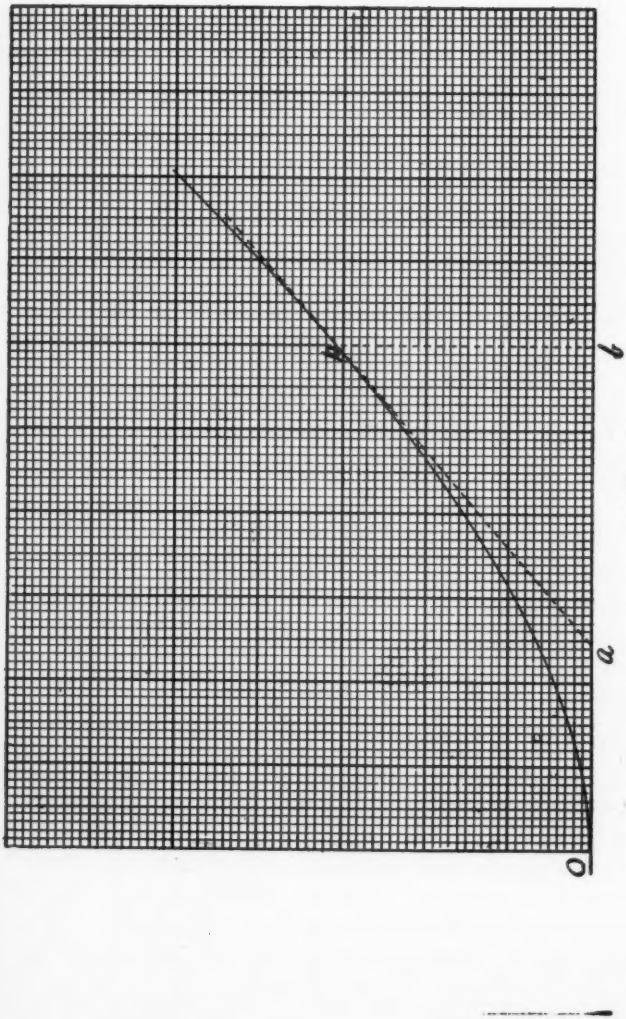


Fig. 1.

may further note, as shown by equation (19), that at the point determined by $x = 1$ the values of m and n are the same, differing at all other points so long as n is not a constant. We may further note that if x or speed is taken in units of knots per hour, it is seldom that the values for $x = 1$ would be known. This is readily avoided by using some other speed as a unit. Thus 10 knots per hour or 10 feet per second might be used, the results corresponding to such unit being usually known.

(14) For the case considered in section (5) the relation between m and n is entirely similar to that discussed in the preceding section. For the case of section (6) the relation is similar to that discussed in section (12), while if B and n are constant throughout as in section (7), the values of m and n are likewise constant and identical throughout.

(15) We have thus endeavored to show the meaning of the exponents m and n as defined, and the relation of one to the other. We will next examine various actual methods for their determination. First, with regard to m, it has been shown that $\frac{dy}{dx} \div \frac{y}{x}$ is the limit of the expression $\frac{\log y_2 - \log y_0}{\log x_2 - \log x_0}$, and, therefore, that such expression, if the intervals are small, may be taken as the approximate value of m for an intermediate point x, y. The actual application of this formula is quite tedious and leaves much to be desired on the score of ease and speed of determination, though it is the one, perhaps, which has hitherto been usually employed for this purpose.

Taking the more general value $m = \frac{dy}{dx} \div \frac{y}{x}$ and supposing the curve traced, we may apply it to the determination of m as follows: In figure 1 let p be the point. Draw a tangent pa. Then $m = \frac{dy}{dx} \div \frac{y}{x} = \frac{pb}{ab} \div \frac{pb}{ob} = \frac{ob}{ab}$ = the value of x divided by the subtangent. The method consists, therefore, in drawing at the successive points tangents to the curve, and dividing the corresponding values of x by the subtangents. This method has the advantages of being exactly applicable to the point in question, and of extreme simplicity and speed of application.

The accuracy is measured by the accuracy with which one can draw a tangent to a given curve, the uncertainty of which affects the length of the subtangent AB. From a large number of measurements made by the author, it seems probable that this error need not exceed about one per cent. In any event it is quite sure that the value of m thus derived will far more accurately represent the true value for the curve than will the latter the true law involved in the phenomena concerned. The value thus found is, therefore, abundantly accurate, taking into account the nature of the fundamental data.

(16) If the data in hand have not been represented graphically by means of a curve, we may find the value of m as follows:

It is well known that were the curve traced, the direction of the tangent at a point determined by $x_1\, y_1$, values intermediate between $x_0\, y_0$ and $x_2\, y_2$, would be given approximately by

$$\frac{dy}{dx} = \tan \varphi = \frac{y_2 - y_0}{x_2 - x_0}. \tag{21}$$

We have therefore,

$$m = \frac{y_2 - y_0}{x_2 - x_0} \div \frac{y_1}{x_1} = \frac{x_1 (y_2 - y_0)}{y_1 (x_2 - x_0)}. \tag{22}$$

This formula furnishes a ready, and if the intervals are not too great, a fairly accurate means for the determination of the index m. It may be noted that if the law for the interval between the two points $x_0\, y_0$ and $x_2\, y_2$ is satisfied by a second degree parabola, the value of tan φ above is exact and not approximate.

(17) As a third method, we note that

$$m = \frac{dy}{dx} \div \frac{y}{x} = \frac{dy}{y} \div \frac{dx}{x} = \frac{d(\log y)}{d(\log x)}. \tag{23}$$

Suppose, therefore, that a curve were traced whose abscissa should be log x and ordinate log y. It is then evident that the tangent of the angle of inclination to X of this curve at any given point will be the value of m at such point. In figure 2 let apq be the resulting curve. Then at the point p we have $m = \frac{pc}{bc}$. We have here the same cause and limit of error as in the method developed in section (15). In point of speed there is practically no difference between these two methods once the curve apq at hand. We may note that if m is constant the line

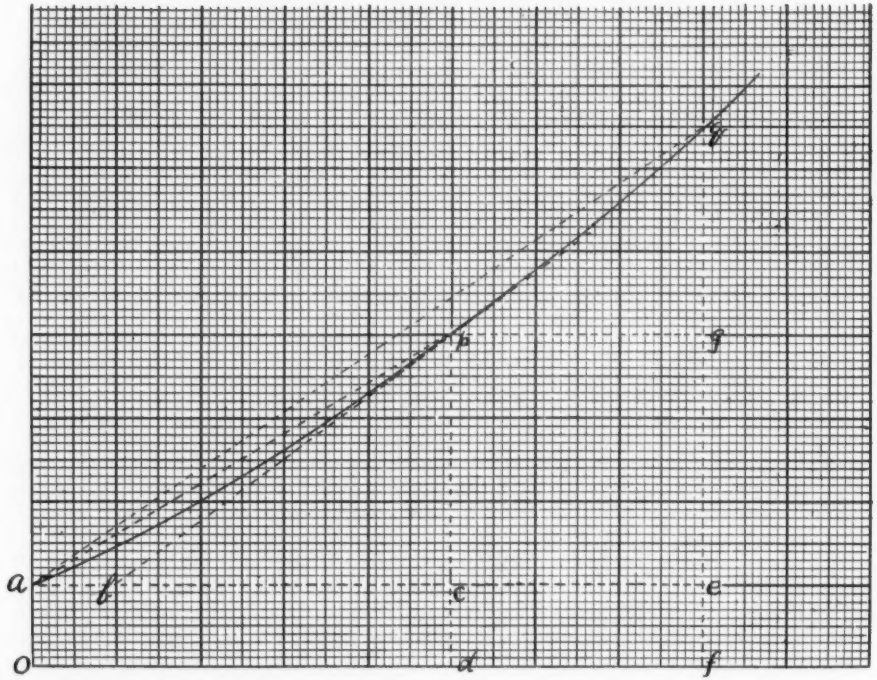


Fig. 2.

apq will be straight, and, therefore, its curvature is at once an indication of the departure of *m* from constancy.

(18) We next turn to the value of *n*. We note first, that if *n* is different from *m* the only case in which it can be determined is that where B is constant.

We then have

$$n = \frac{\log y - \log \mathrm{B}}{\log x} = \frac{\log y - \log y]_1}{\log x}. \qquad (24)$$

In this form the value admits of simple numerical computation. We may obtain the values much more easily, however, by making use of the logarithmic curve of figure 2. Let *oa* equal log. *y* for *x* equal 1. Then *oa* equals B, and *n* equals $\frac{pc}{ac}$. In other words, *n* is the tangent of the inclination of a line drawn constantly from *a* to the varying point *p*. This process involves no inaccuracies whatever, except such as are inseparable from all graphical constructions.

Fig. 2.

It is apparent that should *apq* be straight, *n* as thus determined, becomes equal to *m*, as we have seen that it should. The values of *n* determined in this case will depend on the exact value of *x* which is taken as the unit. That is, the values of *n* are entirely definite and can be determined in any given case, but such values will correspond to the particular amount of *x*, taken as a unit. This may be illustrated by reference to figure 2. As there plotted, O*a* is the value of *y* for $x = 1$, and is therefore the value of B. It follows, as already seen, that for the point Q and for this value of unity, the value of $n = \frac{qe}{ae}$. Suppose next, that for unity on X, a new amount be taken such that its log is O*d*. Then *df* which is O*f* − O*d* is the log of the ratio between the quantity corresponding to O*f*, and that corresponding to O*d*. But this ratio is the measure of the former in terms of the new unit, and therefore *df* is the log. of such measure. That is, in terms of the new unit, *df* is the value of log. *x* for the point *q*. It is also evident that *dp* = the value of *y* for $x = 1$, and therefore *dp* = B. Therefore in terms of the new unit, *n* for the point *q* equals $(qf - dp) \div df$ or $n = \frac{qg}{pg}$. Similarly for other

points, the values of n will equal the tangents of the inclinations of a line drawn constantly through p and to the point in question. For any proposed value of x as a unit, therefore, we have simply to find the corresponding point p, on a logarithmic curve as in figure 2, and through such point a line drawn to any other point, q will give a line, the tangent of whose inclination will be the value of n for such point q. There may be, therefore, as many sets of values of n as there are points on the curve, each one corresponding to some particular value of the unit on X.

The particular use of the index n lies in the possibility of thereby representing the continuous relation between y and x by an equation in the form $y = B\,x^n$. This use is in no way impeded by the possibility of the multiple series of values. Once a convenient unit adopted, the values are thereby rendered definite, and the representation may be made in the form proposed.

(19) It is readily seen that the logarithmic curve furnishes the simplest means for the investigation of the values of these two exponents m and n.' The initial plotting of such curves, however, is rather tedious, and the author has had prepared for this purpose, as well as for many other like uses, a form of cross-section paper with logarithmic scales each way instead of the usual plain scales. With this paper the plotting of a curve showing log. y in terms of log. x is as readily carried out as is the plotting of the ordinary curve on the usual cross-section paper. By this aid several examples and applications of the preceding principles have been worked out as follows:

(20) Figure 3 gives a representation of the equation $y = 2\,x^3$ plotted on ordinary cross-section paper. Here $B = 2$ and $n = 3$ and both are constant. These values are denoted by the line *bc* for B and *de* for n.

Now, arbitrarily a line, *fg*, was taken to denote a series of varying values of B for values of x between 1 and 9. The values of n necessary to fulfil the equation were then found as represented by the locus *hk*. We thus see that the loci *fg* and *hk* represent a pair of series of values of B and n, which satisfy the original equation quite as well as do the constant values $B = 2$ and $n =$

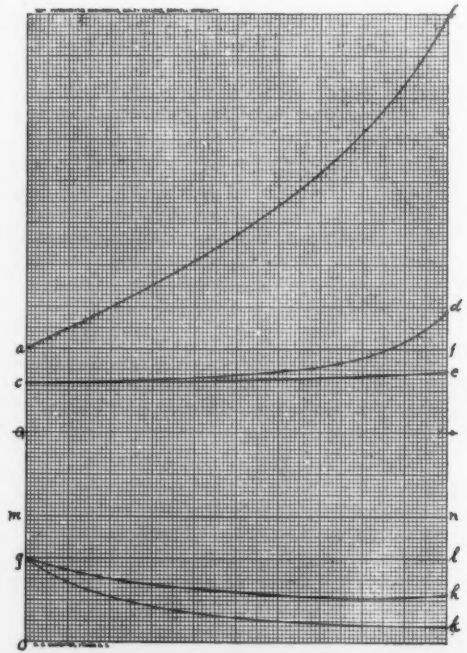


Fig.4.

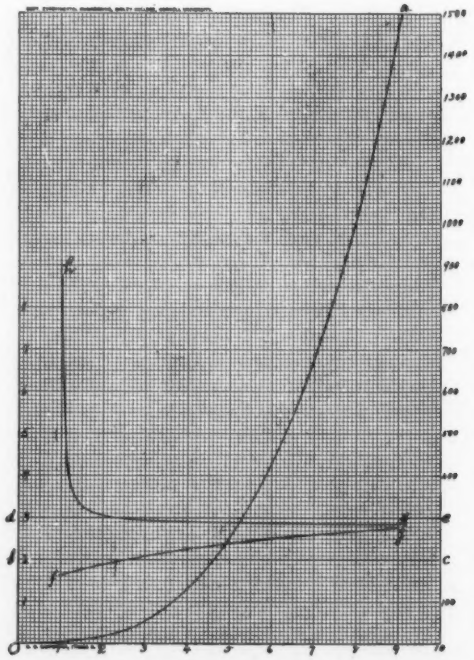


Fig. 3.

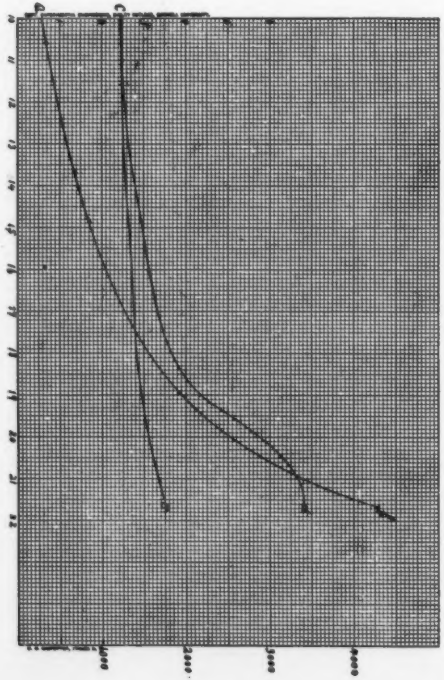


Fig. 6.

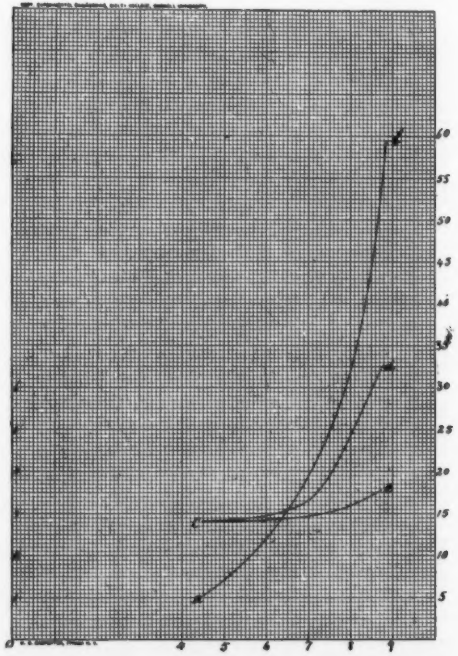


Fig. 5.

3. It is furthermore evident that we may have as many such pairs as we choose. This illustrates the absence of definiteness, which results from an absence of conditions relating to either n or B, and shows that any given curve conceived as referable to an equation of the form $y = B\,x^n$ may have an indefinite number of sets of values of B and n, provided the latter are unrestricted.

In Figure 4 *ab* referred to an origin O_1 shows the form of a curve, $y = B\,x^n$, when B has a constant value, 2, and n is a variable as determined by the locus *ce*. The loci *af* and *ce* may then be considered as determining a pair of sets of values for B and n such that the equation is satisfied. Suppose now that we choose to consider n as a constant and B a variable. Taking $n = 2$, we find a series of values of B represented by the locus *gh* referred to origin O. Or again, if we take $n = 3$, we find B represented by the locus *gk*. We have thus determined three pairs of sets of values of B and n, any one of which will satisfy the original equation, and in two of these n is a constant, while in the other B is a constant. This further illustrates the points mentioned in connection with figure 3.

With regard to the index m we note that in the case of figure 3 its value must be constant and equal to 3 no matter what values may be given to B and n. Similarly in figure 4, m has a definite though not a constant value. It is represented by *cd*, and remains unchanged no matter what values may be taken for B and n.

(21) In figure 5 we have the speed curve of the barge reported by Chief Engineer Isherwood in the JOURNAL, Vol. I, No. 1, page 1. The locus *cd* shows the values of the exponent m, while *ce* shows those of n, the unit speed for the latter being taken as 5 knots. Similarly in figure 6, we have the speed curve of the *Vesuvius* from the values given in the JOURNAL, Vol. 1, No. 1, page 82. Here, likewise, *cd* and *ce* give respectively the loci of the exponents m and n, 10 knots being the unit speed for the latter. In figure 5 it is seen that m begins at a value about 2.8 at 4.5 knots, increasing very slowly to 3.3 at 7 knots. From this point it jumps rapidly to a value 6.4 at 8.7 knots. A somewhat similar, but less uniform variation may be

noted for *m* in figure 6. Here the increase is slow from 10 knots to 19, at which point the index suddenly rises to a value 6.7 at 20 knots, after which it remains nearly constant for the remainder of the curve.

One can but regret that the information should stop at this point. We are here evidently approaching a point in the periodic variation of resistance and speed where the index, after passing a maximum, may again decrease; but as to just where or to what extent, we must remain ignorant so far as the data furnished by this curve are concerned.

In figure 7 we have these same curves laid down on logarithmic cross-section paper. In this diagram *ab* is the curve corresponding to figure 5, plotted with 5 I.H.P. as a vertical unit; *cd* is a straight line drawn at an inclination whose tangent is 3, and therefore represents a cubic curve. It is readily seen just where the given curve has an inclination less than, equal to, or greater than this line, and, therefore, just how the variation of power with speed stands in relation to the index 3. The rapid departure of *ab* from *cd* at points beyond 7.5 knots indicates the same rapid growth of the index *m* which is plotted in figure 5. The values given in figure 5 were obtained from the curve of figure 7 by careful measurements of the inclination at successive points. We may note in passing that it is possible to draw a tangent to a curve with the slight curvature of those in figure 7, with considerably greater certainty than to those having the more rapid curvature found in speed curves as usually plotted. In *ef*, figure 7, we have the curve for the *Vesuvius* with 500 I.H.P. as the vertical unit, while *gh* is a tangent line corresponding to index $m = 3$. In *klmn* we have the same locus with 250 I.H.P. as the vertical unit. The two loci are in fact the same curve, one being shifted vertically relative to the other. In the second case the smaller unit has enabled lower speeds to be plotted, while the greater range has made it necessary to plot the last end at *mn*, considered as relating to units of the next higher order. That is, the point *q* for example, corresponds to 10.4 knots speed and $1.3 \times 250 = 325$ I.H.P., while *s* corresponds to 20.75 knots speed and $13 \times 250 = 3250$ I.H.P.

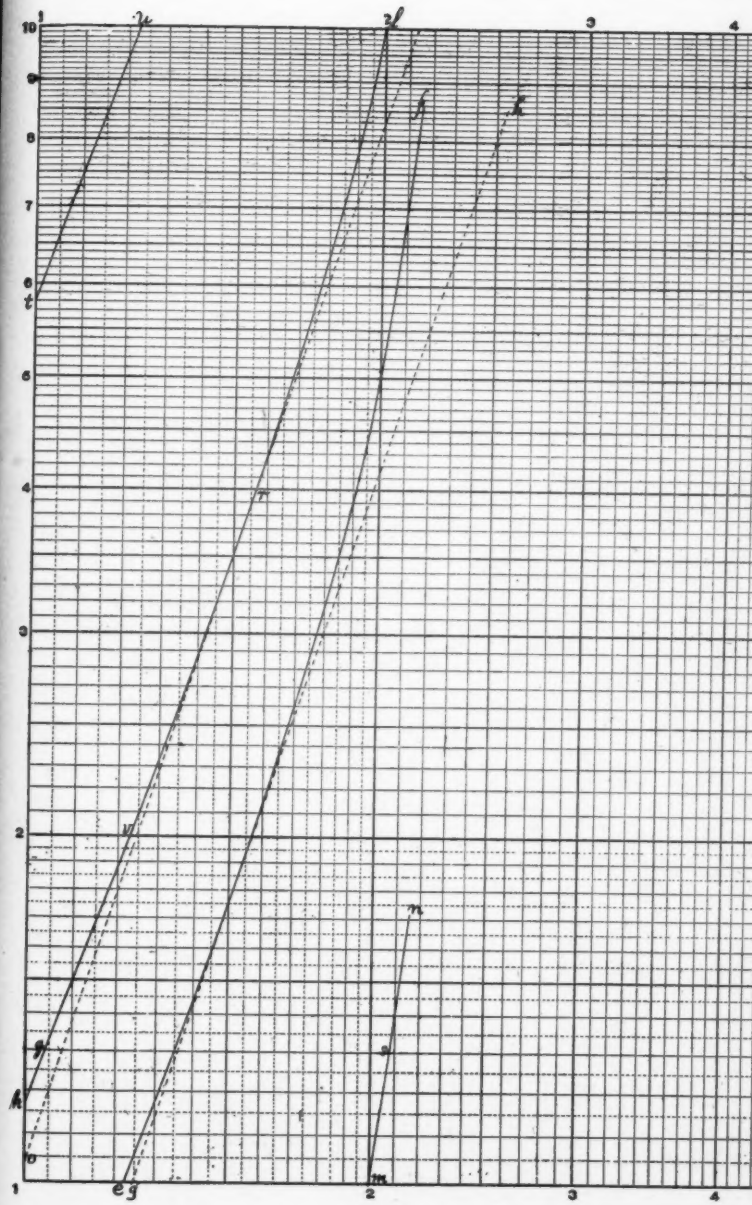
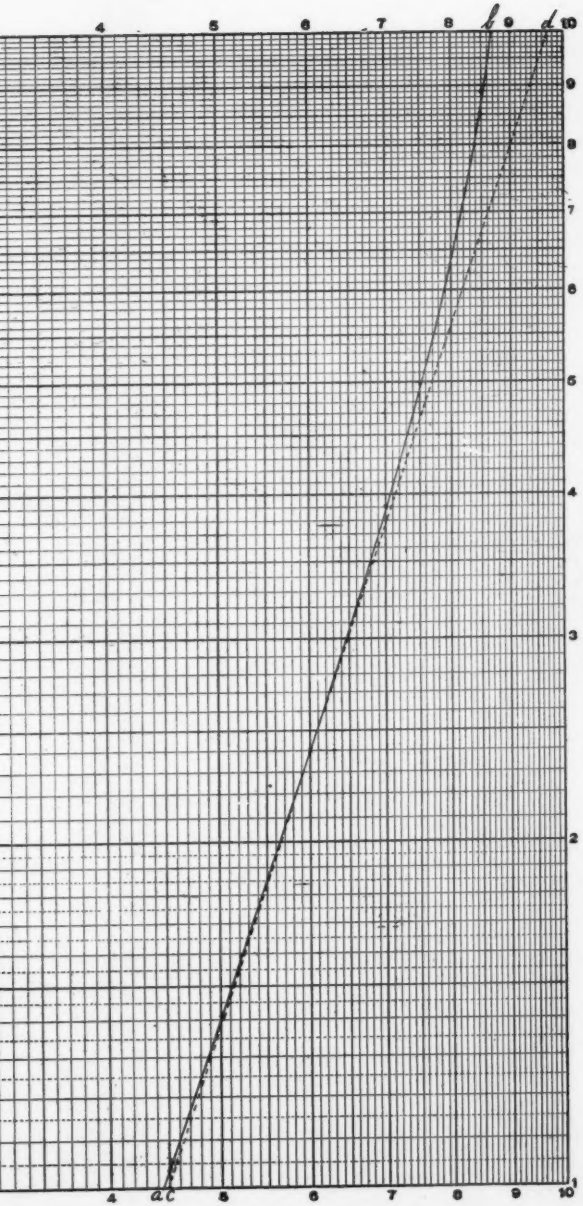


Fig. 7.



g. 7.

A little consideration of the nature of these logarithmic curves will show that no change of units whatever, will change their inclination at any given point, and therefore, that the value of m is independent of the units employed, as it should be, while n is dependent on the unit only, as the latter fixes the point on the curve through which the lines determining its value are drawn. If it seems desirable to avoid plotting the curve in parts, as *kl* and *mn*, it is quite easy to paste two sheets together so that the upper lines shall coincide, and the axes of Y shall lie in the same line, and then extend the plotting on in a continuous curve. The vertical distance between like points on *ef* and *kl*, is exactly log. 2, being the log. of the ratio between the units of I.H.P., 500 and 250. With the former unit, points for speeds less than 12 25 may be plotted on the top of the sheet as at *tu*, which represents the part which would extend below the lower line, were the plotting to be carried down in a continuous curve below *e*. As plotted at *tu*, the unit is of one order below that for *ef*, and therefore, each unit here represents 50 I.H.P., instead of 500. In this case as in the last, the plotting of *tu* may be avoided by join ing a second square to the lower side of the diagram, and then carrying *fe* downward in a continuous curve.

(22) Another interesting point in connection with the index m for the *Vesuvius* is the low value which it has for moderate speeds. For speeds between 10 and 12 knots its value is nearly constant at 2.5. At first sight this might seem to indicate too small a value for the index of resistance variation with speed. It must not be forgotten, however, that while we have for good reason assumed the general form of the curves under consideration to be referable to an equation of the form $y = B\,x^n$, yet in the case of a speed-power curve the circumstances would be more correctly represented by the form $y = B\,x^n + C$, C being the initial or constant engine friction. No form of analysis of the curve itself, however, would enable us to thereby determine C, so that there is no advantage in assuming this form of equation rather than the first. It is evident, however, that if a curve really of the form $y = B^1\,x^{n^1} + C$ is represented by an equation $y = B\,x^n$, the index m will be less for the latter case than for the

term $B^1 x^{n1}$ in the former. This is because the addition of a constant term brings about for the whole quantity a slower apparent variation of y with x than that which exists for the variable term $B^1 x^{n1}$. It is also evident that for small values of x the value of C will be relatively large, and therefore this effect will be more marked at low than at high speeds. If now in any given case we knew what the value of m should be, we could easily find the constant value of C, which, being subtracted from y, would give this value of m. If, for example, we assume that m at 11 knots should be 3 instead of 2.5, we find that a subtraction of about 40 I.H.P. would make this change, while for $m = 3.1$, the amount to be deducted would be about 50. Absence of all certainty as to what m should be, however, renders it useless to attempt the estimation of C in this manner. This reference to engine friction and to its influence on the form of the equation, is only to be considered as incidental here, since in the present paper we are dealing with cases where the equation is either truly of the form $y = B x^n$, or where it is unconditionally so assumed.

We have in the preceding paper endeavored to show the nature of the two exponents m and n, as defined, together with improved methods for their computation. The significance and use of these exponents, is too well known to require especial notice. It may be suggested for extrapolation, that is, for the determination of the I.H.P., for a speed slightly above or below the limiting values given, that the curve for n, from its slow variation, seems to offer a somewhat greater assurance of accuracy than the speed curve as usually plotted. The same advantage may be suggested with regard to the logarithmic speed curve as shown in figure 7, which from its slight curvature may be extended with somewhat greater certainty than the usual form.

SPECIFICATIONS.

By Theodore Cooper, C. E.

[Reprinted from the "Polytechnic" of the Rensselaer Polytechnic Institute.]

When you enter upon the active work of your future profession, you will find that the construction of Engineering works is done through the medium of a class known as contractors; men who undertake the execution of the plans of the engineer, under certain conditions and with the perfectly legitimate and proper intention of making a profit from the performance of the required work.

While an engineer may occasionally have an opportunity to execute a piece of work, by the direct method of purchasing the material and by the employment of labor by the day, such a method is one of exceptional experience.

Work may also be designed and executed by the cut and try method or practically without any true engineer or contractor. But the general rule and the method pointed out by experience as the best is the proper formulation of a definite plan by the engineer and the letting of the execution of the same to a contractor; either by a private or public letting.

The letting of a contract may be made in various manners, according to the character of the work or the restrictions placed upon the parties controlling the same.

Work done under City, State or National control is usually opened to all bidders under certain legal restrictions; and the lowest bidder must be given the work, frequently without regard to his want of knowledge or experience in the execution of work of the kind contemplated.

Work of other kinds may be restricted in competition to a selected or invited class of bidders, with the intention of excluding incompetent or undesirable competitors.

Or, again, under other circumstances the work may be given to some one selected contractor, without any competition, upon his own estimate, or an estimate agreed upon by both parties.

The contractor is entitled from a business point of view to a reasonable profit upon the work executed, and I think you will find it the universal testimony of experienced engineers that, were it within their power, they would never allow a contract to be made which did not contain the expectation of a reasonable profit to the contractor.

This is not to be understood as meaning a profit to the contractor under all circumstances, but only upon the condition that the work has been properly and economically executed.

In preparing the estimate of cost of any particular piece of work, it is the duty of the engineer and the contractor to add to the approximately known elements of cost, a profit for the execution of the same and also a contingent fund proportional to the risks involved and to the unknown elements entering into its execution.

If the expected risks do not occur or should the unknown elements prove favorable, the contractor, of course, obtains a larger profit due to these assumed contingencies; and he is justly entitled to the same.

The universally recognized principle in all business, that the expected interest or profit from any investment must be in proportion to the risks, applies also to the execution of engineering works. I consider it important to impress upon you this principle, for it is not always borne in mind by those whose careers run in professional lines.

Some years ago, it was deemed important to build the piers for a bridge at a most unfavorable season of the year, in a river subject to sudden and severe floods.

It was recognized that the chance of loss of the uncompleted work would be very great; the importance of the new connection was considered as sufficient to justify the attempt. Only one contractor of those invited to bid, would give any figures for executing the work. He submitted with his bid an estimate of the cost for doing the work, and to this he had added a profit

and a lump sum to reimburse him for the possible loss of his plant and such part of the work as would be liable to destruction if a flood should occur during the execution of the work. The offer was accepted, and by promptness of execution and a favorable season, the work was completed without accident; the contractor, necessarily and properly, making a proportionally large profit.

At a future date, an engineer, appointed to report upon the expenditures, in the interest of an opposing faction, noted this work as an extravagant one, because the prices per cubic yard were far above the customary prices in that region. The work having been under my supervision I was called upon for an explanation. Upon presenting the facts of the case, the action was approved as in accordance with correct business principles.

Failure to recognize this principle, that the contingent profit should be in proportion to the risks, sometimes causes great injustice to worthy parties, who are allowed to enter upon work, in which the parties in control, fully realizing the great risks, know that the contractor's contingent profit is in no manner proportional to the risks envolved.

The United States, through their agents, the Lighthouse Board (in their report for June 30th, 1890), recommend the awarding of the contract for the construction of the Hatteras lighthouse, off the Outer Diamond Shoals, upon a plan and bid, which they state contains a profit to the contractor of only 9 per cent., *upon the supposition that he sustains no losses.*

In other words, upon a work where the risks were considered so great that the contractor was to construct and operate the lighthouse for a year after its completion, without receiving any payments; for the construction of which there were no precedents; which is a work so important to our great commerce that a Nation like the United States should construct it regardless of its cost; the agents of this great Nation demand a structure upon which the contractor has but 9 per cent. to cover contingencies.

An absolute profit of this amount would be expected for the construction of a country barn.

The contractor, to whom the above contract was awarded, attempted to execute this contract; he lost his caisson and plant within a few days after reaching the shoals, and was compelled to abandon the contract after losing a sum of money amounting to about 20 per cent. of the contract price.

Within a short time it has been stated that the Lighthouse Board have prepared plans for this structure, which they estimate can be built within the appropriation (500,000 dollars), and give the contractor a profit of 20,000 dollars, or 4 per cent. ! ! !

If we recognize the principle, that the contingent profits must be in proportion to the unknown elements and the risks involved in the execution of a proposed work, it becomes the duty of the engineer to reduce these unknown features to a minimum as far as may be possible, before receiving bids.

This is best done by a well designed plan, a thorough study of the local conditions, and a carefully drawn set of specifications based upon the theory of possible contingencies.

This is no ordinary task, for it involves not only a thorough knowledge of the subject, with a broad experience in the execution of similar works, but also an ability to express clearly each particular and to avoid unnecessary and annoying requirements or the hampering of the freedom of methods, which it may be best to leave to the contractor.

It needs careful study to cover fully and distinctly all the requirements of the work so that the plans may be executed without unnecessary extra charges to cover neglected features, and also to avoid severe and impractical demands, which would only enhance the cost of the work without obtaining a better final result.

Engineering specifications are the detailed particulars supplementing and explaining the plans of any piece of work, and governing the character of the materials and the methods of construction to be used for the same. Or where unaccompanied by plans, are the rules and directions under which any work is to be designed and executed.

Their purpose is a two-fold one:—First: They are to enable bidders upon any work to understand fully the character and

extent of the work and what they are expected to furnish and what to do, in order that they may be able to make suitable estimates upon which to formulate an intelligent and proper bid. Second: They are, in connection with the plans, to serve as the reference in regard to all questions as to qualities of the materials and workmanship, during the execution of the work, in order to avoid misunderstandings between the engineers and contractors; the contractor not being allowed to furnish poorer or less suitable materials and workmanship than is there specified, nor the engineer to demand any better without giving an extra compensation. Nothing serves better to obtain the best class of contractors and to obviate much of the friction which occurs during construction between the engineer and the contractor, than a good specification, carefully and clearly expressed.

A loosely drawn and incomplete specification is always attractive to the worst class of contractors, or those who do not intend to do an honest job and who will take advantage of every weak point to get all they can out of the work.

Not unfrequently such men bid low for work, which is not carefully guarded by a strong specification, trusting to get additional pay or profit, either through extra claims or by substituting inferior material or work.

Specifications vary much in their forms and methods, due to the particular character of the work they are intended to cover and the theory upon which the work is to be executed. They may be general in character so as to cover any works of a similar kind, or they may be special and apply solely to one particular example.

They may be attached to carefully detailed plans, or only to a general plan, or in some cases be unaccompanied by plans of any kind.

As the specifications and plans are intended to supplement and explain each other, the specifications must be full and explicit upon all points which cannot be or have not been fully represented on the plans, and, for brevity, it is seldom customary to repeat or describe in the specifications, features which have

been fully illustrated upon the drawings. It is done sometimes, however, for special reasons; for example, the specifications for the improved sewerage pumping engines, city of Boston, give not only a general description of these engines in connection with a detailed set of plans, but also a detailed description of each piece forming a part thereof; the special merit in this case being the greater facility given bidders to prepare their estimates.

The descriptive character of the specifications enabled each bidder to take off the various classes of work and quantities of material, with much greater facility and certainty than would have been the case had each one been compelled to compile the data from the drawings which were numerous. Generally, however, such a complete description of parts is unnecessary and useless.

A special specification attached to a set of carefully worked out and fully detailed plans, where all the parts have been proportioned and dimensioned by the engineer, need only consider the proper execution of the plans with suitable workmanship and materials. The contractor cannot be held responsible for any features of the engineer's work. It is, however, usual and proper to require the contractor to check all dimensions affecting the proper assemblage of the parts, before proceeding with the execution of the work. This, however, does not make him responsible for the strength or proper working of the design.

Where a general plan only is furnished, the specifications must cover all the requirements as to the correct proportioning and detailing of the work, in fullest detail. Or, again, if the contractor is to be given the fullest latitude, without even the restriction to a certain general plan, the specifications must be still more general in character. Such a specification must cover all the features affecting the selection of the general plan, the proper proportioning and detailing of all the parts, and must be broad enough to obtain the best results without hampering the designer unnecessarily; this requires a broad experience of the various possibilities and a clear comprehension of the principles of design and the methods of construction.

The character of the specification will be largely affected by the theory upon which the work is to be executed, and the basis on which payments are to be made.

The work may be let for a lump sum of money, to cover the total cost, or the prices may be dependent upon the quantities of the different materials, at various rates per unit of measurement, as, cubic yards, lineal feet, or pounds weight. Where the price is a lump sum, the natural business instinct of the contractor will lead him to lean towards minimum quantities; while for unit prices, the same instinct will tend towards maximum quantities.

In case of less scrupulous contractors, such variations from the normal may be extreme and to the detriment of good economical results.

Of course, you will understand that it is not always practicable to obtain the exact normal dimensions in any work of magnitude; a rock cut, tunnel, embankment, etc., cannot be expected to conform exactly to the neat lines of the plans. Even in a metal structure, like a bridge or piece of machinery where each part has been given a definite shape and dimension, there will be a variation of weight due to the practical limitations of accuracy in the process of manufacture. A reasonable variation must be expected and considered for each case, for it must be paid for in one way or another. By proper provisions of the specifications this variation can usually be restricted within reasonable bounds.

In metal structures it is usually specified that the variation of the actual weight from the theoretical weight, as shown by the dimensions of the parts, must not exceed a certain percentage (usually $2\frac{1}{2}$ per cent.), or such excess will not be paid for; this gives the contractor a sufficient allowance for practical variations in the material, and, at the same time, does not give him enough latitude to favor a tendency in either direction. In some cases it may be the best policy to restrict the payments to the actual quantities, as shown by the neat or normal dimensions, in order to avoid careless work or undue payments, through favoritism or political or personal influence. Of course this does not mean

that such variations from the neat dimensions, as are to be expected under the best of management, are not to be paid for indirectly.

The experienced and intelligent contractor will simply determine the cost of doing the work in his way, then assess the full cost plus his expected profit, upon the neat quantities, and thus determine the unit prices upon which to base his bid. Before preparing a specification, it will be necessary to decide whether the best policy is to place all the risks for the execution of the work upon the contractor, or to have the company assume part or all of the risks.

It is the duty of the engineer to place before the contractor all the facts he may possess affecting the execution of the work. The engineer and the contractor can both form an estimate of the possible risks, according to their individual experience of similar work.

The contractor's estimate of such risks will, as before explained, be incorporated in his contract price and must be paid for by the company. It is well to consider if the estimate put upon these risks by the contractor is a fair one under the circumstances. If it is exorbitant and out of proportion to the anticipated risks, it may be considered best by the engineer or his employer for the company to assume the risks in some form or other.

Or it may be that the risks are of such a character they cannot or should not be placed on any other party.

As an example, many railroads erect their own bridges, and build all work which in any manner could interfere with the safety or proper operation of their train service. Where the risks are such that injury may fall upon the company, through the ignorance or carelessness of the contractor or his forces, a power of control and direction should be more explicitly retained in the engineer than where such losses fall solely upon the contractor.

Where there are several classes of materials and workmanship which are to be paid for at different rates, it is very essential that each class be properly and clearly defined.

There is no general classification of materials universally accepted, and, considering the varying conditions to be met with in the various parts of our country, it would be difficult to formulate any general and definite set of definitions, and still more difficult to give such definitions legal weight.

It is best, therefore, to describe in the specifications the various classes of materials and workmanship which will be used as the basis of all payments.

The materials of excavation, varying from the softest muck or most fluid quicksand to the hardest rock, may be classed together as "Materials of Excavation," and be paid for at one uniform price (rarely done), or they may be divided into a number of grades, usually as earth, hard pan, loose rock and rock, the line of demarcation between the classes being defined rather by the relative difficulties of removal of the material than by any of the ordinary definitions or acceptations of these terms.

The different kinds or classes of masonry must likewise be described, for the terms in use in one region may cover an entirely different or less suitable class of work in some other; what may be the "best" in one district may be second class in some other, where better stone and better workmen are to be had.

In like manner all other materials and workmanship must be defined.

The use of such general terms as "first-class" material, "best workmanship," &c., carry no weight except where they are expressly defined or are taken in connection with other definite clauses.

As it is the engineer's duty to determine whether the specifications are being complied with, he must be able to determine and decide if the materials and the workmanship are of the desired kinds; he should, therefore, know before drawing up the specifications what materials and what class of work are needed, and make the same clear so that the contractor can have the same knowledge.

The average contractor is quick to discover the engineer's want of knowledge, and is prone to take advantage of it. Make it your study, then, to know thoroughly the various classes of

materials and work, so you can define them in the specifications, and also know whether you are getting them during the construction; otherwise your ignorance will soon be found out, and advantage taken of it by the less scrupulous contractor.

Or, on the other hand, you may do an unfair act by making a well meaning and honest contractor replace by your final "best" something which he had a right to think was the intended article.

Do not use ambiguous terms or expressions. Do not lay traps for the contractor; it is not an honorable act.

The contractor has his rights, and the engineer who fails to give equal consideration to the rights of his employer and the contractor in the execution of any work falls short of duty.

Remember that your position as an "engineer" is something higher than that of an advocate or partisan; that while you are bound to render loyal service to your employer, by devoting to his service your time and talent, such service may not pass the bounds of truth, honor or justice.

One of the highest honors of your profession is the attainment of such a reputation that both parties to a contract willingly accept your decision as final in all matters of dispute.

Neither have you the right to insert such clauses as "to the satisfaction of the engineer," or "as may be directed by the engineer," to be afterwards used for obtaining more or better material and workmanship than would be expected from the context of the specifications.

They can, however, be used to cover work or material which could not, under the circumstances, be otherwise defined. Or they can be used to relieve the contractor, under special conditions, by accepting some other material or work than the specified ones, if the engineer considers the same as satisfactory and more expeditious.

Contingencies often arise in the execution of work where certain materials cannot be obtained with sufficient promptness, or where changes must be made in order to complete the work at the required time.

In such cases the interests involved may justify a change of plan, and the contractor may properly be compelled, if the fault be his, to replace the intended work or material by something more expensive. In such cases, however, the engineer should be just and not take advantage of the circumstances. Where there are alternate methods of doing the work equally well, or where there may be permissible latitude in the selection of the material, it is best to formulate the specifications to allow freedom of selection to the contractor, for frequently each bidder may have better facilities in some one direction than in another. You will thus obtain closer bidding, and, during the construction, more expeditious results.

Again, where different materials and different methods may not be equally good, it may be your duty, after consideration of the relative costs and merits, to select those which are not the absolute best, but the best which the funds devoted to the execution of that particular work will permit.

Avoid as far as possible specifying proprietary articles or processes, as somebody's paint or cement, somebody's forms of iron or steel, somebody's valves or special mechanism.

Usually the merits of any desirable material or process can be defined, so that if there be others perhaps unknown to you, which are equally good, they may be allowed to be used. It is a natural tendency, after having had a favorable and satisfactory experience with some particular thing, to desire to specify it for other cases, and you will be constantly requested to do so by the persons interested in it.

You will find, however, that such action tends to two results, which are undesirable; first, a suspicion that you had an interested motive for thus specifying, and, second, that you are paying more for these things than you would have done under a free competition.

It is, however, sometimes admissible to specify that the materials or process must be equal in character and results to some well-known article or process.

In like manner it is better to exclude an undesirable proprietary article by a well-defined clause stating the required merits

of the desired thing, rather than give an appearance of prejudice by forbidding its use.

As the preparation of an original specification requires a large fund of practical experience and observation, it is better that your early efforts in this line be based upon well-known existing specifications, modified to suit your special needs.

Before doing this, carefully study the specification which you may select as your model, that you may have a clear understanding of the intent and meaning of its several clauses and of the theory upon which it is based.

Be careful to consider the specification as a whole, and not solely as a collection of disjointed clauses, part of which you may select at random and part reject. Frequently the various clauses are so correlated that, taken separately, the intention of the specification is lost.

By comparison of different specifications of well-recognized merit you will frequently find that, while each may produce equally good results, they accomplish this purpose by different methods or on different theories. By endeavoring to compile a common specification from these several specifications without proper judgment, as is not unfrequently done, a worthless and often absurd result is produced.

In compiling a specification, by the use of old and clearly-defined clauses, do not, without good reason, attempt to change their wording.

You may reduce the force of such clauses by permitting a new interpretation, and lose the strength of an accepted interpretation by other engineers and contractors.

A specification is not intended to be a treatise on the refinements of engineering theory, but a practical set of rules and conditions upon which work is to be let and constructed. A specification should therefore be reasonably brief and positive.

A general specification need not consider and provide for all the special minor conditions and exceptional cases that may possibly occur in practice. It would render such a specification cumbersome and too confusing for practical purposes.

The question often arises, under a general specification, why certain things are required or are forbidden, because there does not appear in some particular case any reason for the clause; or again, there may be clauses which have no bearing in a certain character of designs or certain kinds of work. If, however, the specification is an accumulative growth, as every good specification must be, it will be found that these requirements have an application, either to some fault that may have been corrected by their existence or else that these clauses are needed in the great mass of cases, and it is better to maintain them for the particular case under consideration than to create an exception.

When the special case is one of sufficient importance a special specification should be prepared, taking into account the particular circumstances.

A general specification is intended to apply to the general cases in practice, and where important works of a special character are to be built a special specification applying to the circumstances of that case should be prepared.

A work like the Washington Bridge over the Harlem River should not be built upon a general highway bridge specification, nor should specially important railroad bridges, like the great bridges over the Missouri or Mississippi Rivers or the proposed bridges over the East or North Rivers, be built upon a general railroad bridge specification.

Structures of exceptional character or of special importance should have the professional consideration of a specially qualified bridge engineer, who can give the circumstances of the case full weight. The accepted rules and practice, as applied to the general class of bridges, can be modified and varied from with great advantage to the structure.

There is no inherent principle contained in a specification, however good and perfect it may be, to get good and proper material and workmanship, if left to itself or is placed in hands of inexperienced or incompetent persons to execute or administer.

A specification, also, which contains extra refined, new or severe demands that you have neither the proper experience, time or assistance to enforce, is a mistake; for it means that your

employer will have to pay for something that you cannot guarantee he is getting.

While, therefore, special works of importance may justify the employment of new methods and new materials, you must recognize that to obtain them you must employ extra means of inspection and supervision; must also pay higher prices than for the customary methods and materials.

Do not attempt to rush into new things until you have exhausted the capabilities of the things which are readily obtainable. For general classes of work you will find it better, both in time and money, to make use of the ordinary methods and those materials which are accessible.

There is no better illustration of the difficulties to be expected from an attempt to obtain new materials and to use new methods, or the possibilities of accomplishing excellent results from the means and methods readily obtainable, than a comparison between two important and well-known structures, viz: the St. Louis and the Washington Bridges, two of the largest and most expensive arch bridges in the world.

Both of these bridges were constructed and erected in place under my supervision, so I have knowledge of the comparative difficulties of their construction and the relative merits of the methods employed.

The St. Louis bridge has three arches, two of 502 feet and one of 520 feet clear span.

The Washington bridge has two arches of 510 feet clear span. The total metal, however, in each bridge is not far apart, that of the St. Louis bridge being about 12,000,000 pounds, that of the Washington bridge being about 13,500,000 pounds. The metal work of the St. Louis bridge cost $2,120,000, while the price for the Washington bridge was $845,000.

The time required for the construction of the St. Louis arches was four years and four months.

The time required for building the Washington bridge was only two years and five months.

Of course, in considering these two cases we must allow for the better facilities we now possess for the construction of bridges,

and also for the experience gained during the intervening years; but nevertheless they illustrate the principle I wish to impress upon you, viz: the extra cost and increased difficulties accompanying the demand for new and special materials and processes.

The special design of the St. Louis arches required that new and special machinery should be constructed for manufacturing the shapes and for working these shapes into the finished members. The contractors lost a great deal of money before any successful results were reached. Not only were the forms of material new and difficult to manufacture, but they were also required to be made of a new material, chrome steel. The manufacturers, after great losses, finally succeeded in making the shapes satisfactorily, but not with chrome steel. The recurring failures, delays and accompanying litigation added largely to the cost of an already expensive work. Even with the increased facilities we to-day possess for manufacturing structural work, the St. Louis bridge would be a costly piece of construction if made on the same plans and specifications.

Anyone who contemplates the execution of an important work on some new plan, or with some new and untried material, cannot fit himself better to appreciate his task than by reading the history of the St. Louis bridge.

The Washington bridge, on the contrary, demanded no forms or kinds of materials that were not readily obtainable, nor the development of any expensive machinery.

That this latter bridge is in any manner a less worthy structure, or is less creditable to our common profession, would scarcely be claimed by anyone who is acquainted with the two bridges.

CARE OF MARINE BOILERS.

By Robert Forsyth, Esq., Assistant Manager Union Iron Works, San Francisco, Cal., Associate.

The boilers are the most expensive and perishable parts of the machinery of a steamship, often requiring to be replaced two or three times in the life of a vessel.

Deterioration and decay begin as soon as the boilers are in use, and are only partially prevented by care on part of designers and engineers. At the present time the demand for large and fast steamships necessitates the use of boilers of great size and cost. The attention of builders and owners is, therefore, directed to keeping this portion of the machinery up to the highest point of utility for the longest period at the least expense.

Ten or fifteen years ago, eight years' work was considered a good average for a marine boiler, but the period of usefulness has been increased fully fifty per cent. within a few years. This gain is due in a measure to improved design and construction; but more, probably, to the more intelligent care bestowed upon boilers by modern engineers.

The first and simplest thing to guard against is

EXTERNAL CORROSION.

This arises from various causes, drips from leaky decks, leaky screw-stay bolts, leaky hand-hole plates, joints, stuffing boxes, etc., and from a cause so apparent that it would not be noted if it did not occur so often, namely, the neglect to water-proof portions of the boilers directly under hatch openings.

There is no good reason for the existence of any of these causes of corrosion, yet they do exist and create a constant demand for the boiler maker's panacea—a "soft patch." The most serious point of external corrosion is the front of the ash pan and the adjacent portion of the boiler head. The use of firing tools, wet-

ting down of ashes and other causes, conspire to render corrosion at this point very rapid.

It may be counteracted in part by the persistent use on the ash-pan fronts of the waste oil or grease from the engine room. A better method of protecting this part of the boiler, though seldom applied, is to fit soft patches or wearing plates of $\frac{5}{16}$-inch iron over the seams connecting furnace to front head, and extending over the lower part of the front head, to take in the front seam of the shell. This should be done when the boiler is new, and, although these wearing plates will last only a few years in active service, their renewal is simple and inexpensive, and therefore to be strongly recommended.

Four years' wear in hard service has been had from the wearing patches by keeping them smeared with the waste oils from the engine room.

Wash of bilge water upon the shell is another cause of corrosion, and when the vessel is so designed that it is impossible to prevent the shell being wet by bilge water, it becomes necessary to keep the shells covered with some anti-corrosive material. The writer of this article has had a long practical experience with corroded boiler shells and the many preventives therefor, but has found nothing better or cheaper than coating the boiler shell below the furnace line with a mixture of engine-oil drippings and plumbago while the boiler is warm.

With ordinary intelligence bestowed upon the care of marine boilers, there is no reason why their period of usefulness should be shortened by external decay.

INTERNAL DECAY

is a much more serious matter. The chief causes of trouble inside boilers are: Use of sea water, dirty fresh water, greasy water, cold feed water, imperfect circulation and contracted water spaces.

Using steam at a pressure of 160 pounds per square inch evolves difficulties that did not exist at 75 pounds per square inch. At the latter pressure a little supplementary feed from the salt-water side of the condensers would give a coating of lime

inside the boiler, prevent pitting, and the oil coming with the feed water would rapidly rise in the slightly brined water to the surface, and could be cared for by the scum valve; but while a $\frac{1}{16}$-inch scale on a back tube plate would not cause trouble at a working pressure of 75 pounds per square inch, at 160 pounds per square inch another condition of affairs exists. The tube plates having been thickened for increased temperature, the tube ends will leak from a very slight deposit on the tube plate.

The spray from a leaky tube end wetting the particles of ash, coal and dust carried by the draft forms a deposit on the other tube ends, and the furnace is rendered useless. If two furnaces are common to one chamber, both are disabled, much disagreeable labor is entailed, expanding the leaky tube, and this must be done repeatedly until there is an opportunity to thoroughly clean the boilers.

There is also danger, under forced combustion, of the tube ends leaking enough to cause a back draft from the furnace into the fire room.

In the days of low-pressure boilers a thin scale was considered rather an advantage and protection to the inside of boilers, and it is difficult for engineers accustomed to that type of boilers to realize the changed condition with higher pressure.

Corrugated furnace crowns are seriously injured by even a thin scale, and it will be found that the corrugations near the middle of the grate, perhaps a little nearer the furnace front, suffer most. At this point the repeated opening of the furnace doors, and consequent change of temperature, causes the scale to crack, a new coating is formed, is again cracked, and so on repeatedly until, in some cases which have come under my observation, the scale, after a twenty days' run, had formed in leaves attached to the corrugations like the leaves of a book to the binding, with the open edges of the leaves, about one inch over all, toward the front of the furnace and the attached edges, about $\frac{1}{8}$ of an inch thick, toward the back.

This shows that the evaporation is much greater at this part of the boiler; also that the corrugated furnace, if of good material, actually performs the duty for which it was designed, viz:

expands and contracts without tearing the connecting seams of the tube sheets.

In the effort to prevent the formation of this scale it is customary to stop the supplementary salt-water feed, and use instead distilled water from the evaporators. This frequently leads to serious trouble from the presence of grease in the feed water. Deposits of grease on the hotter parts, such as furnaces, lead to overheating and collapsing of furnace tubes; also to leakage at laps of back connections.

In parts of the boiler where less active generation of steam takes place, pitting is sure to follow. The under sides of boiler tubes suffer most; also the sides of furnaces about the line of the grate bars; the rounded part of flange of back tube sheet, and sides and bottom of combustion chamber, below the approximate line of upper grate bars and near the water line on shell and heads.

The pitting in these places is rapid and frequently unobserved in the earlier stages, the pitted parts being covered with a black, moderately hard oxide, which, being removed by thorough washing and scraping, discloses the true condition of the metal attacked.

To prevent this overheating and pitting, from the presence of oil or grease, many remedies have been used with varying results. Filters of various kinds, are among the most successful devices, sometimes applied on the suction side and sometimes on the delivery side of feed pumps. These filters are of various materials—sponges, blankets, coke, charcoal, gunny-sacks, horsehair, tan bark, hay, etc.—each being strenuously advocated by its particular selling agent, but the results depend more upon the care and judgment exercised by the engineer than upon the material of which the filter is made.

The filter which presents the greatest surface in a given space, which can be readily replaced, and the material for which can be obtained at any port at small cost, will commend itself to engineers. But a filtering tank, filled with ideal material, will mechanically trap only a small percentage of grease, if the filtering material is not frequently cleaned and renewed.

The designer of a filtering tank should bear in mind that the location, accessibility and facility with which covers and interiors can be removed and replaced, is of vital importance. Wass' air and grease extractor has been used with more or less success, depending upon the care and judgment of those using it. This filter is an enlarged chamber, on the discharge side of feed pipe, with cross bars inside giving passage for the water, alternately over and under; a float operates an air and grease escape valve; by-pass valves and mud blow-off valves are also provided. Its operation is based upon the fact that the lessened velocity of the water in the enlarged chamber gives time for the grease to come to the surface and be automatically blown off by the accumulation of air operating the float valve. The mud, if any, will settle to the bottom and be blown off.

On one of the Puget Sound Steamers, having a compound engine fitted with slide valves, and using a working pressure of 120 pounds per square inch, this filter was used, but the engineer, considering the amount of oil used on the valves excessive, stuffed the spaces between the division plates with hay, thereby greatly increasing the utility of the grease trap. The hay was renewed every day. Hay stuffed in gunny sacks and blankets has been used with advantage in ordinary feed tanks, care being taken that all the feed water passes through the filtering material.

Efforts have been made to catch the grease in the main engine exhaust pipes, hoping thereby to keep the condenser as well as the boilers clean, but reports are conflicting as to the success of this device.

Feed heating arrangements assist materially in getting rid of grease. Gilmour's feed heater is a large chamber, fitted between feed pump and boiler, necessarily a few feet above the working level of the boiler, into which is discharged, about half way up, the feed water, filling the heating chamber about two-thirds full. A little below the feed inlet is an internal perforated steam pipe with suitable regulating valve. The steam by direct contact heats the water almost to pressure point, and the sludge is precipitated to the bottom of the chamber.

A triple-expansion engine of about 1,500 I.H.P., fitted with this heater, has been under my observation for three years, and, with no other grease extractor, the boilers have been kept absolutely clean while on quite a hard service.

Cold feed water is injurious to boiler shells, furnaces and furnace seams, and feed water should be heated to within a few degrees of the steam temperature before being discharged into the boiler; but this practice is not in general use. Weir's feed heater is one of the best in use, but is cumbersome, has many valves and pipes, requires two pumps, and the temperature is limited, being on the suction side of pump.

Direct injection of steam into the ordinary feed tank, and heating by coils in tank, are open to the same objections. Discharging into the boiler with a series of inside pipes renders boiler cleaning more difficult. Heating the feed water by direct contact with steam, as by Gilmore's heater, before mentioned, is so simple and satisfactory that it seems to meet all requirements.

When feeding with water from rivers or city supply, the direct contact of steam for heating, in a large chamber, where the velocity would be low, would precipitate most of the earthy matter.

Efforts have been made to neutralize the effects of oil in boilers by injecting sal soda, caustic soda, lime water and potash with the feed water; but as the best cylinder oils are pure mineral oils and do not saponify, the results have not been satisfactory.

Zinc slabs, in parts of the boiler showing decay, seem to retard it somewhat, though a large quantity, sometimes amounting to tons, has been used without satisfactory results.

It will be found that boilers fed by an independent feed pump with feed water (from a surface condenser, *not leaking*), aided by an evaporator, filter and heater, have very little tendency to pit below the line of the grate bars when an efficient system of mechanical circulation is maintained.

The use of the hydrokineter warms the water in lower parts of boilers when getting steam, but constant circulation is neces-

sary, especially under banked fires, and the water should be pumped continually from lower front end of boiler to upper back end.

The value of this simple method is greatly underestimated, and on many vessels the pumps are not fitted up for the purpose. Constant circulation by pumping prevents the lower shell seams being strained by unequal expansion, and reduces pitting below the grate line to a minimum. The benefit derived from constant circulation below the grate level seems apparent when we consider how little pitting takes place between the grate line and top of combustion chamber. In two-furnace boilers pitting below the grate line is greatly in excess of that in three-furnace boilers, a difference due to the better circulation maintained in the latter by the location of the middle furnace.

The tubes used in most vessels at present are greatly superior in make and quality to those in use fifteen or twenty years ago, and when of No. 8 or No. 9 gauge, will last six or eight years, giving little trouble. If only of standard thickness, however, which does not allow sufficient margin for scale spots and other surface imperfections, constant leakage will occur, whereas in the thicker tubes the result would be only an increased roughness of the surface.

If tubes are placed too close together cleaning is difficult, and tubes are liable to be burned at the back ends from an insufficient supply of water to tube plates. Tubes spaced to give 50 per cent. water surface to tube plate give practically no trouble, but if spaced to give only 40 per cent. are likely to make the water in boilers foam, and give endless trouble to keep back ends of tubes tight in the tube sheets.

When the tubes are overcrowded in the boiler various methods are resorted to, such as ferrules and cements, to prevent leaking of tube ends. But all such devices are merely temporizing with the difficulty, which exists primarily in the defective design.

The use of steam at 160 pounds per square inch has led to the abolition of that danger trap, the superheater, one of the most formidable foes of the old-time boiler room, fitted, as they were, with one, two, three or four vertical flues hooped with angle

irons, and usually too narrowly spaced to permit inspection. Corrosion and pitting could go on *ad libitum*, and usually the first intimation of trouble would be the bulging of the flues. The interior could not be examined without cutting the shell.

Now that boilers are made a little larger, giving more water surface for steam to escape, the necessity for a superheater no longer exists, nor do the difficulties which it was intended to obviate.

On the flame side of the furnace decay takes place at the point of contact with the bridge wall, and as the deterioration covers a large surface it is apt to escape detection until the plate is quite thin. By placing thin sheet iron between the bricks and the furnace plate each time the bridge wall is rebuilt the decay may be retarded. Around the manhole joint, in the interior surface of the plate, pitting occurs partly from the presence of sulphur in the rubber gaskets, and partly from repeated buckling opening the surface of the plates.

The wear of boilers depends much upon the character of the service in which the vessel is employed. Tug boats, bay steamers and coasters, in the order mentioned, seem to suffer more than ocean steamers.

Irregular application of heat, lying under banked fires for long periods, and irregularity of washing out boilers, will account in a great degree for this difference.

The care of a marine boiler when not steaming is of great importance. If empty, it should be quite dry; if it contains water, it should be *quite full* and have no leaks. Sudden stopping of engines, without an independent air pump to care for the steam, is a constant source of injury to boilers, as it is difficult to check the pressure without notice. There is, of course, no difficulty with independent air pumps to care for the steam.

The use of forced draft has added to the difficulty of caring for boilers, especially with the closed fire-room system, as the admission of cold air when the furnace doors are opened is the worst possible treatment for back connections and tubes. The induced-draft system is little, if any, better, either with the fan or the jet in the smoke stack. The alternate high and low temper-

ature from the immense heat of the fires, and the inrush of cold air when the fires are replenished, demands a very elastic duty from materials and conditions that are the reverse.

Forced draft with the closed ash pit system, affords better control of the steam making power, and depends less upon the trim of ventilators or direction of the wind, especially in the tropics, where fire-room duty is always severe. It is also free from the great objection of admitting a rush of cold air when fires are replenished. The main objection to its use is the increased length of fire room required with the ordinary type of marine boiler, but its use in moderation is extending, and all the appliances to supply it are of the most permanent and durable character.

This system does away with the difficulties arising from handling coal from different bunkers and discharging ashes, which are encountered with a closed fire room, and the longest voyages may be made with a regularity of steaming impossible with a closed fire room or natural draft.

The foregoing remarks apply particularly to the ordinary type of marine boiler, but of late years the demand for high pressure and less weight per horse power has brought into use various forms of water-tube boilers, the care of which is equally important. All that has been said as to the necessity of supplying pure water is more imperative with the water-tube boiler than with the older type. Being more flexible, the water-tube boiler suffers less from forced draft with closed fire room, but, being more susceptible to change of temperature and having a small storage of water, will suffer greater loss, from a steam-making standpoint, than if used with closed ash-pit system. The rapidity with which steam can be raised from cold water, and the reduced weight per horse power, ensures favorable consideration for this type of boiler. But the actual durability is yet to be demonstrated.

The life of grates, bridge walls, and furnace fronts depends almost entirely upon the coal used. With Pacific Coast, Australian, Japanese, Chilean and the lower grades of English and Scotch coals, the furnace fittings wear well, the linings of the

fronts and doors suffering most when the fire is too near the front. With good grades of Welsh or Pennsylvania coal the wear is much greater, especially if dampers are used suddenly to prevent blowing off steam when it is necessary to stop the engine quickly.

The most durable grate bars are the thinnest, and wrought iron is preferable, as these can easily be straightened or pieced out aboard ship, when cast iron ones might not be obtainable.

Breechings, front connections and doors, require constant attention when lignite or flaming coal is used, and if not kept in repair add to the consumption of coal and interfere with the draft. With patching and repairing, front connections, doors and uptakes will usually last as long as the boilers; not so with the smoke-stack. In active service, ten years is a long life, but this, again, depends on the quality of coal used. If flaming coal is used the smoke-stack has a very short life, not more than three years with some of the lignites.

The outside of the smoke-stack is protected by paint, but as yet we know of nothing that would afford protection to the interior. A few vessels are provided with hoods to protect the smoke stack when laid up, but these are seldom used when the vessel is in commission.

It is the custom of late years to cover the greater part of boiler shells with non-conducting material, and to cover this again with some water-proof material, either sheet lead, galvanized sheet iron or painted canvas. If either of these water-proof coverings are permitted to leak; the non-conducting material, being porous, absorbs the moisture and causes corrosion. There are numerous non-conducting coverings which, when properly put on and kept water tight (which is seldom), will last as long as the boiler.

Bottom and surface blow-off valves, feed-check valves and gauge cocks require constant attention. The scour from blow-off is particularly bad on the seats of the blow-off valves, and, if neglected and permitted to leak, entails serious trouble with blow-off pipes. These valves should be ground in or faced up frequently. In using the blow-off at sea the gradual and simultaneous closing of outboard and inboard valves will greatly re-

duce wear on pipes. In these pipes the dynamic effect of the sudden change from cold water to hot pressure, and reverse, is very great and will sometimes split the heaviest pipes.

The gauge cocks must of necessity be blown through to keep them free, and if the composition contains zinc they last but a short time. I have renewed them after three months' wear, when the keys looked more like sponge than metal.

Boilers well designed, constructed of the best materials and equipped with the most approved fittings, may be a source of constant annoyance and expense for lack of intelligent care in the matter of raising steam and blowing off the water. If boilers and pipes are slowly and equably warmed before pressure is raised, a most fruitful source of leakage is avoided.

When, at the end of a voyage, steam pressure is blown off, dampers and doors should be closed and the water left in the boilers to cool gradually (a couple of days if practicable) before being pumped out. Attention to these details will be well repaid by the absence of leaks, which are inevitable when boilers are blown out with steam pressure.

The length of time a boiler of the present type may be used varies so much under different conditions that it is difficult to arrive at a satisfactory average.

I may instance two sets of boilers, of the same type and on similar service, one set of which was renewed after eleven years service.

These boilers were steam tight at a working pressure of 60 pounds, and from the furnace side were apparently as good as ever. Yet the back connection sheets were found to have been reduced in thickness by decay from $\frac{7}{16}$ inch to barely $\frac{3}{16}$ inch in thickness. Where decayed the combustion chamber had only $1\frac{1}{2}$ inches to 2 inches space between that and the shell.

The other set of boilers, having $3\frac{1}{2}$ inches to $4\frac{1}{2}$ inches water space around combustion chamber, was found to have worn very little at these points, and was continued in service three years longer.

Another marked instance has come under my observation, where the machinery of two vessels on same service show marked

difference in wear. The boilers in one vessel required renewal after seven years' service, while in the other they have now been running sixteen years, and appear to be good for many years more. In the latter case the same chief engineer has had charge of the machinery from the beginning of service.

In one instance, of boilers thirteen years old, I had the back tube plate (after the boilers were cut apart) knocked around with sledge hammers until it was doubled over upon itself, without showing any sign of cracking; and I think something similar will be found with the majority of old boiler plates *if the material has been good*, when the boilers are new.

As boilers have been built and equipped, their life has been about 12 years, with pressure from 60 to 90 pounds per square inch, and while they could be repaired and run longer at lower pressures, it would not be a commercial success to do so.

Among the many old boilers I have repaired or removed, I have found that, as a rule, comparatively little decay has taken place above the bridge walls, and the shells were pretty good except the lower parts, but the furnace, ash pan, lower back connection and lower stays made me wonder how it was possible for the parts to hang together and stand a pressure test.

With the superior quality of steel available for the construction of boilers at the present time, drilled holes, improved workmanship, and the use of corrugated or other elastic furnaces, the life of boilers may be much longer than formerly. Sufficient water spaces around the connections, evenly distributed bracing, tube space not crowded, the use of hot, filtered feed water, and mechanical circulation of water in boilers, will, I think, with the renewal of tubes and furnaces, prolong the life of marine boilers to nearly twenty years, under the supervision of intelligent engineers, notwithstanding the fact that the pressure has been advanced to 170 pounds per square inch.

"Eternal vigilance is the price of safety" in the case of steam boilers, and the engineer who despises small things will be continually beset with small troubles, which, in the aggregate, will greatly reduce the period of service of boilers and engines.

CONCLUSIONS AND RECOMMENDATIONS OF THE COMMITTEE APPOINTED BY THE LORDS COMMISSIONERS OF THE ADMIRALTY TO CONSIDER EXISTING TYPES AND DESIGNS OF PROPELLING MACHINERY AND BOILERS IN H.M. SHIPS.

5, CRAIG'S COURT, CHARING CROSS, *9th December, 1892.*

The Committee appointed by the Lords Commissioners of the Admiralty to consider existing types and designs of propelling machinery and boilers in H.M. ships, and to make suggestions for the improvement of the same in future, have now the honor of submitting their final report on the several points referred to them.

As to reduction of working pressures.—As the reduction of working steam pressure mentioned in enclosure to Admiralty letter S. $\frac{3066}{3362}$ of 15th March, 1892, would, if adopted, effect a radical alteration as regards the machinery and boilers supplied for some time past to our war ships, the Committee first express their opinion on the definite points raised in this enclosure, beginning with the most important, viz: "Taking all the circumstances of the service for which H.M. ships are designed into account, is a reduction of the present working pressures considered desirable; and, if so, to what extent? If the Committee should be of opinion that a reduction of pressure is not desirable, the reasons for arriving at this conclusion should be stated."

Evidence as to economy.—(*a*) The relative economy in working with high and low pressure steam (each in connection with the type of engine suitable for the pressures under consideration) being of the utmost importance, considerable time has been devoted in the examination of witnesses and analysis of the Admiralty records, to elucidate this matter as far as possible. This important question is considered under two heads—1st, for

full power working; and 2d, for low power working, which is so important a feature for war ships.

Economy in mercantile marine.—(*b*) As to economy at full power, all the evidence obtained has been to the effect that a gain in economy has resulted from each successive increase of steam pressure. The replies of the large steam shipping companies show that in the mercantile marine there is an advantage of 20 per cent. in triple-expansion engines using steam of 150 pounds pressure and above, as compared with bi-compound engines using steam of 90 to 100 pounds pressure, and about 25 per cent. as compared with the older bi-compound engines using steam of 60 pounds pressure. The witnesses examined also state the average saving to be 20 per cent. by the use of the triple-expansion as compared with the bi-compound engine.

The Admiralty records for an extensive series of trials made in ships fitted with compound and triple-expansion engines, confirm for naval engines at high powers, the results, as regards economy, obtained in the mercantile marine.

Evidence as to economy.—From all the evidence the Committee consider it established that there is a saving of from about 20 per cent. at high powers to about 17 per cent. at low powers by the use of the high pressure triple-expansion engine, as compared with the 60 pounds bi-compound engine working at similar low powers.

The Committee call attention to the increase in coal consumption per I.H.P. on ordinary low power service, which results in cases where there is a great disproportion between the maximum power and that required for such service.

Advantages of triple-expansion engines.—The triple-expansion principle reduces vibration and the strains on bearings and engine shafting, and thus makes a smoother working engine. Experience shows that the wear and tear with the high pressures is generally no more than with low pressures, and in many cases it is less.

Remarks as to leakage of boiler tubes in reference to high pressures.—In the opinion of the Committee, the use of the higher steam pressures has but little to do with the causes of leaky

tubes, for omitting defects due to design of boilers and details of tubes which equally affect all pressures, it is considered that the tube ends will leak in high or low pressure boilers, if the amount of power attempted to be obtained from them exceeds certain limits. When these limits are exceeded the tube ends and tube plates become overheated owing to the increased generation of steam rendering the local conditions of circulation unable to maintain an adequate flow of water over the surface of the tube plate, and this they regard as the primary cause of the leakage of boiler tubes. It should not be overlooked that concurrently with the increase of steam pressures in our war ships, the powers obtained from their boilers were sometimes unduly increased by forced draft, and the leakage of tubes which followed in consequence should not, in the opinion of the Committee, be considered as caused by high pressures.

Use of fresh water for feed make-up.—The use of fresh water is very desirable in order to prevent the formation of deposits on the heating surfaces, so that ships may always be ready to proceed on any service without delay due to cleaning of boilers. Its use will also be found economical in reducing the labor of cleaning the internal parts of boilers, it being difficult to make some of these spaces sufficiently large and accessible as to be readily and efficiently cleaned.

Leakage of steam pipe joints and glands.—There is no doubt that increased trouble has been in many cases experienced with the higher steam pressures, from leaky steam pipe joints, glands, etc., these not being proportioned to suit the increased pressures. Losses of fresh water and other inconveniences followed, the evaporating plant not being sufficiently large to meet this contingency. Too much attention cannot be given to these details.

Fresh water desirable for lower pressure—Expense of fresh water for boilers.—In the opinion of the Committee, it is desirable that all ships having surface condensers should be supplied with the means of avoiding the use of sea water for replenishing the waste of feed water, and thus ensuring the ships being always in readiness for service, as the advantages gained are more than commensurate with the expense incurred, while the incon-

venience caused by the necessity of frequent supplies from the shore will also be removed by the vessels being made self-reliant as regards the production of make-up feed water.

Increase of draught of ships due to reserve fresh-water tanks.—It has been stated that "the draught of water of the ships carrying a reserve of fresh water in tanks has been increased." Respecting this question the Committee consider that if their recommendations as to size of evaporators, detailed later on, be accepted by the Admiralty, there will be no necessity for carrying so large a supply of reserve fresh water in tanks. By raising the power of the evaporating plant to the maximum required, it is considered that the size of these tanks need not generally exceed that required to contain one fourth of the water carried in the boilers at working level, with a minimum stowage of the capacity of one boiler at working level.

Conclusion as to working pressure.—The Committee are of opinion that a reduction of working steam pressure to 60 pounds is both undesirable and unnecessary, and, as any smaller reductions would be also accompanied by similar though smaller losses of efficiency, they consider that no reduction should be made, there being no serious troubles from the use of high-pressure as compared with low-pressure steam, other than due to insufficient provision of fresh water, which can be easily remedied by the proper supply of evaporators, as previously referred to and detailed later on.

General opinion as to naval engines.—The Committee consider that the existing types of triple-expansion engine fairly meet the requirements, but for improvement of future designs offer the following suggestions:

Margin of power.—As bearing on the important question of the economy of the engines at low powers, and preventing undue strains being brought on boilers and machinery by the development of powers for which they were not intended, it is recommended that the size of cylinders and cut-off of steam should, as far as possible, be so arranged that no more than five per cent. beyond the specified full power should be capable of being attained with valves fully open and everything in full gear.

In the past too great a margin has often existed between the specified full power and that which the engines were capable of exerting, and by this means their economy at low powers has been impaired.

Ratio of cylinders.—It is considered that a ratio of low-pressure to high-pressure cylinder volume of about five is the most suitable for 155 pounds steam pressure, this ratio being a fair compromise between the requirements of the development of high power on a moderate weight and space and low powers with as much economy as possible. With this ratio of cylinders the cut-off in the high-pressure cylinder at full power should be such as to make the mean equivalent pressure on the low-pressure piston about 37 pounds per square inch.

Devices to improve economy at low power.—Various suggestions have been carefully considered for increasing the efficiency of the engines at low powers, while retaining the capacity for the development of the maximum power at short notice. Several of these suggestions involve disconnecting the low-pressure engine. This is not recommended, as it is considered that the practical disadvantages outweigh any possible gain in economy.

Trials of Thunderer.—The trials of *Thunderer* show that her engines, as at present arranged, can be made to work economically at low powers, but as it is considered that the performances generally of H.M. ships are capable of some improvement at these powers, the following device for securing the desired end is recommended, viz: To design the slide valves, eccentrics and gear to give the natural-draft power with the best distribution of steam in lead, admission, release and cushioning, and to obtain the extra power beyond natural draft by overlinking or its equivalent, thus increasing the travel of the valve and securing a later cut-off.

Speed of engines.—As regards the speed of the engines at full power, the Committee consider the speeds specified for the existing types satisfactory. With present experience, however, they do not recommend any higher speeds.

Bearing surfaces, strength, &c.—As regards the compactness and accessibility of the machinery, the strength of the various

parts of engines and boilers and the amount of bearing surface allowed, there is no evidence of any insufficiency except as regards the gudgeon bearings of connecting rods. It is considered the action now taken by the Admiralty in fitting wrought-iron case-hardened gudgeon pins, instead of soft steel, will remedy the defects which have occurred in this part of the machinery.

Size of evaporators.—The Committee recommend the fitting of the evaporating plant in at least two parts, and in large ships three parts. These should be fitted so that they can be worked "in series," to obtain a higher efficiency when a less amount of water is required than the maximum output. To enable this to be conveniently done, their arrangement should be specially considered when the machinery is being designed for the vessel.

Waste of fresh water.—(*a*) From the evidence obtained, it appears that if the machinery is in proper condition the waste of water should be well within six tons per day per 1,000 I.H.P. In some ships it is much less, but the amount varies greatly according to the state of the machinery.

Size recommended.—(*b*) It is therefore recommended that the evaporators should be capable of producing at least six tons of water per day per 1,000 I.H.P. at the specified natural-draft power. As these high powers would only be run for comparatively short periods, it is considered that this amount will provide sufficient water for the boilers under ordinary conditions, and also allow a liberal quantity for ship's purposes, the latter being supplied from the ship's tanks on the occasions when the full natural-draft power is being used.

(*c*) In cases where the number of men to be provided for is exceptionally large in proportion to the horse power of the ship, additional evaporative power should be provided, so that the evaporators will, besides supplying a liberal quantity for ship's purposes, be capable of making at least six tons of water per day per 1,000 I.H.P. at $\frac{3}{5}$ natural-draft power.

(*d*) To insure the apparatus being of proper size under the conditions of service at sea, it should be capable in the makers' shops, when new, of producing $\frac{1}{3}$ more than the preceding quantities, this being in accordance with the present practice.

Size of condensers for fresh water.—(*e*) The above recommendations are based on the assumption that fresh-water condensing apparatus will be fitted in excess of the requirements of the ship's company, so that when required, the ship's drinking-water tanks may be filled from this apparatus, so as to enable the water for ship's use to be supplied from these tanks, and the full production of the evaporators therefore made available for supplying the feed-water make up for the short periods during which high powers are run.

Feed pumps, size, &c.—In order to insure efficient feeding of the boilers, it is recommended that the feed pumps should be of such size that they will work at moderate speed at full power with one-half the pumps at work, and that the main feed pumps be fitted with automatic speed-controlling gear when practicable.

Feed-pump connection for circulating water when raising steam.—To reduce the strains on the boilers when raising steam, and also enable steam to be raised more rapidly without injury when required on emergencies, it is considered that connections should be fitted from the auxiliary feed pumps to enable them to circulate the water by pumping it from the bottom of the boilers back again through the auxiliary feed valves.

Type of boiler.—The types of boiler fitted in the ships undermentioned have been carefully considered, viz:

Battle ships, ...	*Royal Sovereign*, *Barfleur*, *Hercules* and *Monarch*.
First-class cruisers, . . .	*Edgar* and *Crescent*.
Second-class cruisers, . .	*Latona* and *Hermione*.
Single-screw gunboats, . .	*Thrush* class.
Torpedo gunboats, . . .	*Jason* and *Halcyon*.

It is considered, omitting matters of detail which will be dealt with later on, that they are all suitable for the naval service.

The following remarks are, however, made with the view of indicating what is considered to be the relative merits of the various types of boiler fitted, with reference to future designs:

Battle ship boilers.—The battle ships are fitted with four-furnace single-ended return tube boilers of three types, viz: those in:—(1) The *Royal Sovereign*, *Hercules*, and others, having two

combustion chambers; (2) The *Resolution* and *Revenge*, having separate combustion chambers for each furnace; and (3) the *Royal Oak*, with three combustion chambers for the four furnaces, the two middle furnaces delivering into one chamber. Of these boilers the Committee consider type (2) to be the best.

Boilers of first-class cruisers.—The first-class cruisers are all fitted with four-furnace boilers of type (1), (the early ones with double-ended boilers and a small single-ended auxiliary boiler the later ones with single-ended boilers). It is considered that they would be improved by fitting a separate combustion chamber to each furnace as in type (2), or by fitting three combustion chambers as in type (3).

Boilers of second-class cruisers.—The second-class cruisers each have three furnace boilers, some of them with single ends and others with double ends. All have a separate combustion chamber to each furnace, and these types are considered to be well suited for the naval service.

Boilers of gunboats.—The gunboats of the *Thrush* class are fitted with navy boilers with two furnaces; this type is considered to be satisfactory, but some members consider it would be improved by fitting a separate combustion chamber to each furnace, while the other members think such alteration unnecessary.

Boilers of torpedo gunboats.—The torpedo gunboats of *Jason* class are fitted with wet-bottom locomotive boilers having divided furnaces; this type is considered to be suitable for the requirements of such vessels.

Double-ended boilers with combustion chambers common to opposite furnaces.—The Committee have stated their general preference for a separate combustion chamber to each furnace in return-tube boilers, but they consider, however, that the double-ended boiler with combustion chambers common to each pair of opposite furnaces is also an efficient type.

Single versus double-ended boilers.—The Committee consider that either single or double-ended boilers of the types mentioned above will be satisfactory, but that for greater subdivision of

power single-ended boilers are to be preferred where the extra weight can be allowed.

Use of four-furnace boilers.—They further consider that where the extra space required can be given, three-furnace boilers are superior to and should be adopted in preference to four-furnace boilers. The latter should be fitted only for ships in which a limitation of the floor space occupied by the boilers is so important as to necessitate the employment of very large boilers, in which three furnaces, if fitted, would be too large in diameter.

Size of boilers.—As regards the size of boilers recommended—

The return-tube boiler is first considered under the heads of (*a*) heating surface; (*b*) grate surface, and (*c*) steam space.

Proportions of heating surface, etc.—(*a*) As to heating surface, the Committee consider that an amount of total heating surface equal to about 2.5 square feet per I.H.P. at natural draft should be provided.

(*b*) As to grate surface, an area equal to about $\frac{1}{33}$ of the total heating surface is recommended.

(*c*) As regards steam space, the present practice of the Admiralty is considered satisfactory.

Size of navy type boilers.—For the navy type boilers fitted in the sloops and gunboats, the present practice as regards heating surface, grate surface and steam space at natural-draft power is considered satisfactory.

Torpedo gunboat type.—In the torpedo gunboat type of boiler, a total heating surface of about 2.5 square feet per I.H.P. at natural draft is recommended, and the present practice as regards steam space and grate area is considered satisfactory.

Water spaces.—As regards water spaces (other than between adjacent tubes), it is considered that these might with advantage be somewhat increased from the size which have in many cases been recently fitted, in order to facilitate cleaning of the boilers and the free circulation of water.

(*a*) For return tube boilers it is recommended that these water spaces should not be less than in the boilers of the *Crescent.* In the case of four-furnace boilers with two combustion chambers,

as in type (1) referred to previously, each nest of tubes should have a water space down the middle of not less than 7 inches.

(*b*) For the navy type the water spaces should not be less than adopted in the boilers of the *Thrush*.

(*c*) For the torpedo gunboat boilers of the *Jason* class the water spaces are considered satisfactory.

Diameter, thickness and pitch.—Tubes having a diameter of $2\frac{1}{2}$ inches outside, thickness of .16 inch, and distance apart in the vertical direction of 1 inch, for the return-tube and navy type boilers, are considered satisfactory. As regards the distance apart in the horizontal direction, an increase is considered desirable. This distance is recommended to be not less than $1\frac{1}{8}$ inches.

(*a*) For the torpedo gunboats it is considered that the diameter, thickness and distance apart of the tubes, as now being fitted in the *Jason* class, are such as will give good results, these dimensions having been considerably increased from the earlier examples of this type of boiler.

Width of combustion chamber.—A large combustion chamber is advantageous, not only for the combustion of the gases, but for convenience of repairs, and it is considered that a larger combustion chamber than is generally used could be fitted with advantage, the gain derived from the more perfect combustion of the fuel gases more than balancing the extra space and weight involved.

(*a*) In return-tube boilers, with the proportions recommended, the combustion chambers should generally be not less than 2 feet 3 inches wide for those with separate combustion chambers, and 4 feet for double-ended boilers with opposite furnaces common, while for those of large size the width might with advantage be somewhat further increased.

(*b*) In navy-type boilers, the present practice of combustion chambers about 3 feet 3 inches long is considered satisfactory.

(*c*) In torpedo-gunboat boilers of the *Jason* class, the distance between the tube plate and the end of grate is considered to be satisfactory.

Amount of forced draft.—With the sizes recommended the Committee consider that the specified forced draft power should

be limited to 25 per cent. beyond the specified natural-draft power with the return-tube and navy type boilers, and 40 per cent. with the torpedo-gunboat type.

Furnaces and grate.—The Committee recommend that in return-tube and navy type boilers the length of grate should not exceed twice the internal diameter of furnace. They also recommend that the length of furnace should be such that the end of the grate will be at least 6 inches from the combustion chamber.

Tube plates.—Steel tube plates $\frac{5}{8}$-inch to $\frac{13}{16}$-inch thick are recommended for the combustion chambers of all boilers, the former being preferred if the staying can be arranged to suit this thickness.

Boiler tubes, material.—As regards the material of boiler tubes, in many cases the decay of steel tubes from corrosion and pitting has been found to be more rapid than that of iron tubes; while, on the other hand, steel tubes have advantages in their capability of being removed for cleaning purposes, stretched and replaced, which cannot be done with iron tubes, so that for the latter important reason no change of material from the present practice of mild steel is recommended.

Special fittings for boiler tubes.—In connection with boiler tubes the following have been under consideration, viz: (*a*) The fitting of spiral retarders in the tubes; (*b*) "Serve" ribbed tubes; (*c*) The combination of (*a*) and (*b*).

Only by careful experiment can it be determined whether the economy of coal due to fitting them is such as to warrant the extra weight, the interference with cleaning of the tubes, and the reduction of draft when fans are not required to be used.

The Committee do not propose to delay their report by carrying out such experiments, but would, however, recommend that they be undertaken to elucidate the above points.

Systems of draft.—The various systems of supplying the necessary air to the furnaces for combustion of fuel have been carefully considered.

Induced draft.—(*a*) As regards "induced draft" it is recommended that no further experiments be carried out, pending the approaching trials of the *Gossamer*, with this system.

Closed ash pit system.—(*b*) With reference to the comparative merits of the "closed stokehold" and "closed ash pit" systems, as the latter does away with the necessity for a closed stokehold with air locks, and difficulties with ventilation of bunkers when stokeholds are closed, the balance of advantage and disadvantage is considered to be such that the system is recommended for trial in a vessel.

(*c*) As to air heating appliances, which are not applicable to the closed stokehold system, it is recommended that experiments be undertaken to show whether the benefit to be derived by their use is sufficient to compensate for the additional weight and space entailed.

Grease filters.—Grease filters for the feed water are recommended to be fitted to all new ships.

Tubulous boilers.—The Committee recommend the fitting of tubulous boilers in two vessels for experimental purposes.

Tubulous boilers for ordinary war vessels.—It is considered that only those tubulous boilers that are fitted with straight tubes of comparatively large diameter, arranged so as to be readily cleaned and examined, should be considered as suitable for trial with the view, if found satisfactory, to their being fitted in the larger class of war ship.

Having regard to the importance of the subject, the Committee would recommend that these experiments be made without delay, so that data may be obtained for guidance, as to the adoption or otherwise of this type of boiler. In view, however, of the requirements of the larger vessels, they further recommend that one at least of any new cruisers should be arranged to receive tubulous boilers, should the above trials prove satisfactory.

Test of Speedy.—They also consider that the *Speedy* should be thoroughly tried as soon as possible, to determine if boilers constructed with small tubes are suitable for continuous service at sea.

The Committee acknowledge the great assistance that has been so readily granted them by many of the leading engineers in the country, and by the various Steamship Companies and

Engineering firms, with their Principals and Officers, who have afforded them information of great value.

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In conclusion the Committee desire to place on record their high appreciation of the valuable and arduous services rendered by Mr. H. J. Oram, R.N., as Secretary to the Committee. His practical and scientific knowledge, and unremitting energy in obtaining from all sources the necessary information bearing upon the subjects under discussion has materially assisted the Committee in conducting the enquiry and framing their report, and they desire to bring these services to their Lordships' favorable notice.

ALEX. BULLER, *Vice-Admiral and Chairman.*
JOHN H. HEFFERNAN.
J. T. CORNER.
JAMES T. MILTON.
H. J. ORAM, *Secretary.*

(to *)

I fully concur in the above report except as follows:

The proposals involved in the preceding recommendations considerably reduce the powers which are now obtained from a certain weight of boilers. For example, in the *Latona* class, which, as now designed, have given satisfactory results, the maximum power for the present weight of boilers would be reduced from 9,000 to less than 7,000 I.H.P., which appears unnecessary. I am of opinion that the *Latona's* boilers, as now fitted, are amply large for the requirements of the Admiralty, and further, that those of the *Royal Sovereign* class are large enough for the maximum power of 13,000 horses, provided the boilers are fitted with the Admiralty cap ferrules, which have been proved to be effective in preventing leakage of tubes.

With reference to the type of boiler, I am of opinion that the double-ended boiler with opposite furnaces common is a superior type to that with separate combustion chambers, and that the double-ended boiler with one common combustion chamber, as in *Vulcan*, *Thunderer*, etc., is an efficient type. The

performances of the *Thunderer's* boilers since the Admiralty cap ferrules were fitted were highly satisfactory, the weight of water evaporated per pound of coal per hour being exceptionally high.

With reference to the use of high *versus* low pressure steam for war ships, the fuller information obtained, and the investigations made by the Committee, show conclusively the advantages to be obtained by the use of high pressures, and I fully concur in the conclusions on this point embodied in the above report.

W. CASTLE.

While fully concurring with the Committee's report, I am strongly of opinion that all boilers intended for use in Her Majesty's Navy should be tested by water pressure to twice the intended working pressure prior to their acceptance from the contractors, and that their scantling, staying, &c., should be such that no part thereof would be unduly strained when subjected to the test. These views, if accepted and acted upon, would tend to the factor of safety being raised, and to an improvement in the workmanship of the boilers, and also render practicable the application of a more severe test to high-pressure boilers on service than is the practice at present, all of which would, in my opinion, be conducive to greater safety, more especially in the case of boilers which are difficult to clean and examine.

PETER SAMSON.

I fully concur in the report of the Committee, except that I am of the following opinion respecting certain paragraphs, viz:

That a piston speed of 800 feet per minute for engines as fitted in the second-class cruisers, and 750 feet per minute for the engines fitted in the battle ships should not be exceeded.

That for the required full power on emergencies the bearing surfaces of journals of crank shafts and connecting rods should be increased in the I.P. and L.P. engines up to 8 per cent. according to the relative proportion of power and weights under which these journals work.

That the main shafts, more especially the crank shafts, have too much material bored out of the center, whereby the strength

is reduced to withstand the various strains, and I consider the bore should not exceed one-fourth of the diameter.

That the engine beds and framing might be increased with advantage six per cent.

As regards the strength of the various parts of the boilers, as in the *Royal Sovereign*, that they compare favorably with the rules for strength in the mercantile marine, except the cylindrical shells and the main longitudinal stays. The former should be increased 10 per cent. and the latter 15 per cent., while the hydraulic test should be increased to one and three-quarter times the intended working pressure.

Do not consider four-furnaced boilers as suitable for forced draft and closed stokehold or practical working under full-power conditions in the service.

That three-furnaced boilers, having furnaces from 3 feet to 3 feet 8 inches mean diameter as a maximum, should be fitted, having circumferential shells in proportion up to 15 feet diameter for practical working under all conditions, and that 3 feet 6 inches is a preferable diameter of furnace generally for forced draft.

That the furnaces have separated combustion chambers, and where weight and space is limited for double-ended boilers, that a common combustion chamber to two opposite furnaces is preferable and practicable, as in use in the fast and hard-driven mail steamers in the Atlantic service, both with natural draft and closed stokehold and forced-heated-air draft.

That the locomotive type of boiler in use in the service worked under the conditions of "forced draft" is not suitable for torpedo gunboats in rough weather, being difficult to manage on account of the large flat surfaces exposed to intense heat, large grates and confined water spaces. For moderate weather, but with increased water spaces and shorter grates, they are suitable for short service if they have reliable feed appliances.

As regards the "navy" type, they are more suitable for rough-weather conditions; but that tubulous boilers, with tubes rising diagonally or slightly curved, where there is little or no tube plate exposed to intense heat due to large grates, will be found better adapted for large power for this class of vessel in rough

weather and short service, provided the feeding arrangements are reliable.

That the present practice under forced draft should be the minimum capacity, and could be increased in some cases with advantage.

That these spaces are too little under forced draft, and recommend an increase.

That the water spaces round 2½-inch tubes under forced draft should not be less than 1¼ inches.

That the specified forced-draft power should not exceed 10 per cent. above the specified natural-draft power in return tube and navy type boilers, and 15 per cent. in the torpedo boat boilers, but in tubulous boilers it may be increased to 40 per cent., and that under these conditions the higher powers required in the service can be maintained at sea.

That the length of grate for practical working should not exceed 6 feet, and that where a high forced-air pressure is necessary this length should be reduced. The furnace tubes containing the grate should not be less than 7 feet 6 inches in length, increasing in proportion to the diameter of furnace, and the end of grate bar should be not less than 10 inches from end of furnace.

That good iron tubes are most suitable and have less risk of leaky joints in tube plate.

That retarders are essential and necessary under forced draft for 2½-inch tubes and upwards.

That the closed ash-pit system, using heated air above and below furnace bar, has additional advantages besides those mentioned, viz: less risk of leakage, easier worked and more economical, and that the cold-air pressures, where closed stokeholds are used, should be considerably reduced, they being liable to severely affect the intensely heated surfaces of combustion chambers and tube plates.

That where tubulous boilers are used the feeding arrangements should be of a thoroughly reliable character.

G. W. MANUEL.

On the foregoing report "Engineering" of May 12 makes the following editorial comment:

The "Conclusions and Recommendations of the Committee appointed by the Lords Commissioners of the Admiralty to Consider Existing Types and Designs of Propelling Machinery and Boilers in H.M. Ships," has just been published in the shape of a Blue Book. It is a comparatively brief document, considering the amount of evidence of which it is the outcome, and the importance of the subject of inquiry. Only the report itself is published, the reference not being given, and there being no minutes of evidence. It is possible that there were grave objections to making public the evidence of some of the witnesses examined, although, we think, the majority—at any rate, the most important—would have made no objection to their views being laid before the public. However that may be, engineers at large have to be grateful that the report itself has been put at their disposal. Their gratitude need not prove an overwhelming burden on the score of any addition made to their store of technical knowledge.

The report comes to us so shortly before going to press that we have not time to discuss the facts set forth—meager as they are—with that detail which the importance of the subject demands. We will, however, take a cursory glance at some of the more salient features. The first matter considered is a proposal to reduce the working pressure in warships, with a view, presumably, to remove the defects under which the machinery of the ships in the Royal Navy has of late suffered, although no reference is made in the report to anything so irregular as naval breakdowns. Considerable time was devoted by the Committee to the examination of witnesses and analyses of Admiralty records. The question of reduction of pressure was considered under two heads: 1. Full-power working; and, 2. Low-power working. In regard to the first point, "all evidence obtained has been to the effect that a gain in economy has resulted from each successive increase of steam pressure."

Some outline particulars in this respect are given, but they are of so elementary a nature, and must be so familiar to all me-

chanical engineers, that we will not trouble our readers by repeating them. It is a little late in the day to announce—although the information may possibly be fresh to the Lords Commissioners of the Admiralty—that the mercantile marine have made a gain of 20 per cent. or so by the introduction of triple expansion and steam at 150 pounds pressure, as compared with bi-compound engines using steam at 90 pounds to 100 pounds.

What the Committee say as to the gain by working with low powers is of more interest, although the point is not one of such great importance outside the Navy. "The Committee consider it established that there is a saving of about 20 per cent. at high powers to about 17 per cent. at low powers, by the use of the high-pressure, triple-expansion engine, as compared with the 60-pound bi-compound engine working at similar low powers." It appears to us that the last word but one in the quotation just made must owe its presence to a clerical error. At all events, the meaning is not clear. One might expect that the information given would be more ample, especially when we gather, as we do by a side reference, that their lordships, when they appointed the Committee, asked that they should be instructed upon the "reasons" by means of which the Committee arrived at a decision on this matter. We could, however, speak with more confidence did we know what was referred to as saved. Is it coal or steam per indicated horse power? Is the efficiency of the whole machine taken, or only the efficiency of the engine? Again, what are "high powers?" Are they the maximum contract powers with forced draft, or merely a high power with boilers not pressed beyond the normal?

The next morsel of information is on a par with the rest: "The triple-expansion principle reduces vibration and strains on bearings and engine shafting, and thus makes a smoother running engine." The statement, as quoted, stands complete, and one cannot but be struck by the very slipshod aspect it bears. We venture to point out that it would render the statement more complete were the number of cranks specified, a detail which has more influence on strains and vibrations than "triple-expansion."

In the next paragraph we get the ominous expression "leaky tubes;" less ominous, however, since the discovery of the sovereign virtue that lies in a ferrule. "In the opinion of the Committee, the use of the higher steam pressure has but little to do with the causes of leaky tubes." It did not need a congress of engineering Solons to tell us that; although there is this about high pressure and leaky tubes which the Committee might have added. Leaks having been once caused, water will spurt out much more vigorously with high than with low pressures. Admiralty officials have had some forcible object-lessons in this phenomenon within the last year or two. In the next paragraph we find some more unexceptionable sentiments, of which, however, marine engineers, even outside their Lordships' Boiler Committee, may have had a previous shadowy, glimmering intuition. "The use of fresh water is very desirable in order to prevent the formation of deposits on the heating surfaces. * * * Its use will also be found economical in reducing the labor of cleaning the internal parts of boilers." After this expression of opinion it seems almost superfluous on the part of the Committee to add another paragraph to the effect that, "In the opinion of the Committee, it is desirable that all ships having surface condensers should be supplied with the means of avoiding the use of sea water for replenishing the waste of feed water. * * * The inconvenience caused by the necessity of frequent supplies from the shore will also be removed by the vessels being made self-reliant as regards the production of make-up feed water." Here be truths, indeed. The report goes on to quote the fact that "The draught of water of the ships carrying a reserve of fresh water in tanks has been increased," and on this unexceptionable conclusion draws a moral lesson as to the value of evaporating plant. It is a great comfort in dealing with a report of this kind when one feels safe in adopting its sentiments.

Proceeding, we find the following remarks: "The Committee are of opinion that a reduction of working pressure to 60 pounds is both undesirable and unnecessary, and as any smaller reductions would be also attended by similar though smaller losses of efficiency, they consider that no reduction should be made," and

"the Committee consider that the existing types of triple-expansion engines fairly meet the requirements, but for the improvement of future designs offer the following suggestions"—and here we feel that we are coming to something really instructive. The first point dealt with is the margin of power, and in order to promote the economy of engines at low powers and prevent undue stress being brought on boilers and machinery, it is recommended that the size of cylinders and cut-off of steam should be so arranged that no more than 5 per cent. beyond the specified full power should be capable of being attained. The Committee consider that a ratio of low-pressure to high-pressure cylinder volume of about five is the most suitable for 155 pounds steam pressure, this ratio being a fair compromise between the requirements of the development of high power, moderate weight and space and low powers, with as much economy as possible. With this ratio of cylinder, the cut-off of the high-pressure cylinder at full power should be such as to make the mean equivalent pressure on the low-pressure piston about 37 pounds per square inch. The Committee, however, wisely discountenance the disconnecting of the low-pressure engine for the purpose of reducing power. In order to increase the power given off by the engines, it is recommended to design the slide valves, eccentrics and gear, to give the natural-draft power with the best distribution of steam lead, admission, release and cushioning, and to obtain the extra power beyond this by overlinking or its equivalent, thus increasing the travel of the valves and securing a later cut-off. The Committee do not recommend higher piston speeds than at present in use.

As regards the compactness and accessibility of the machinery, the strength of the various parts of engines and boilers, and the amount of bearing surface allowed, they find no evidence of any non-efficiency, except as regards the gudgeon bearings of connecting rods. As most of our readers are doubtless aware, there has been a good deal of trouble in this detail in Navy engines of late. The Committee considered that the action now taken by the Admiralty in fitting wrought-iron case-hardened gudgeon pins, instead of soft steel, will remedy the defects which

have occurred in this part of the machinery. With regard to piston speed, Mr. Manuel, in a separate report, states "that a piston speed of 800 feet per minute for engines as fitted to the second-class cruisers, and 750 feet per minute for the engines fitted in the battleships, should not be exceeded." The question of piston speed is one which is very apt to decide itself when engines are running at sea, but it is right, of course, that a standard should be laid down for purposes of design. Piston speed is like many other good things: one cannot have too much of it as long as it does not disagree with the constitution.

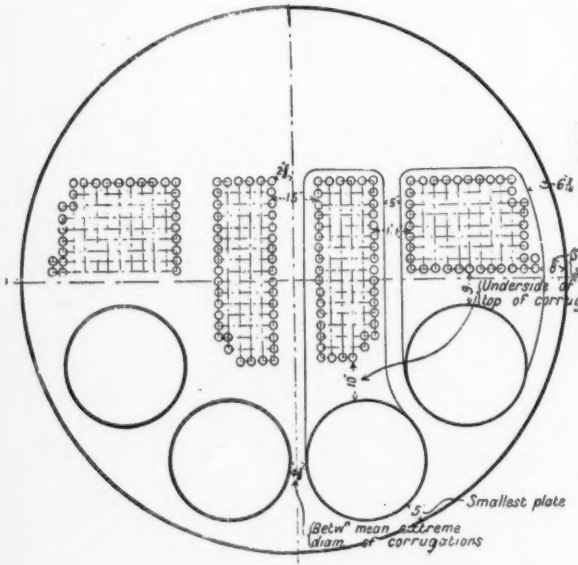
In the course of the inquiry some valuable evidence was given as to the use of evaporators and the requirements for make-up water. The Committee, in the report, recommend the fitting of the evaporating plant in at least two parts, and in large ships three parts. These should be so fitted that they can be worked "in series" to obtain higher efficiency, when a less amount of water is required than the maximum output. The evidence given appeared to show that if machinery is in proper condition the waste of water should be well within 6 tons per day per 1,000 indicated horse power at the specified natural-draft power; but as these high powers would only be run for comparatively short periods, it is considered that this amount would provide sufficient water for the boilers under ordinary conditions, and also allow a liberal quantity for ship's purposes being supplied from the ship's tanks when the full natural draft is being used. In cases where the number of men to be provided for is exceptionally large in proportion to the horse power of the ship, additional evaporative power should be provided.

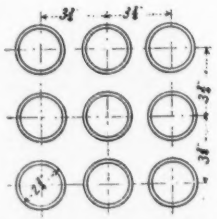
The rest of the report is devoted to the boiler question, the first point taken up being that of feed pumps, in connection with which it is recommended that in order to insure efficient feeding of the boilers the feed pumps should be of such a size that they will work at moderate speed when supplying full-power feed with half the pumps at work, and that the main feed pumps be fitted with automatic speed-controlling gear when possible. In order to reduce the strain on boilers when raising steam, and also to enable steam to be raised more quickly, it is considered that con-

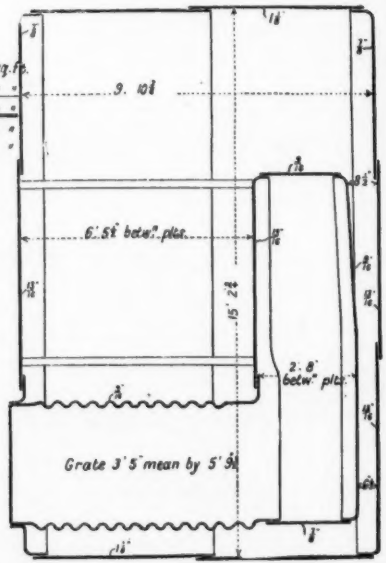
H. M. S. "MONARCH".

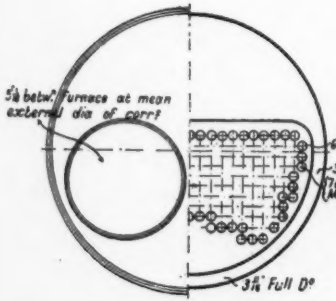
PARTICULARS OF 8 BOILERS.

Heating surface in Tubes	14770 sq. ft.
" " " Furnaces &c.	3720 "
Total heating surface	18490 "
Area of Fire Grate	632·96 "
Area of through Tubes	34·4 "
Diameter of Tubes	2⅜"


6¼ largest plate
Side of tube to smallest plate
Underside of tubes to top of corrugations.
Smallest plate
Betw" mean extreme diam of corrugations

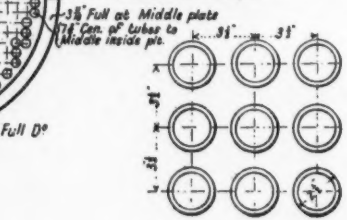


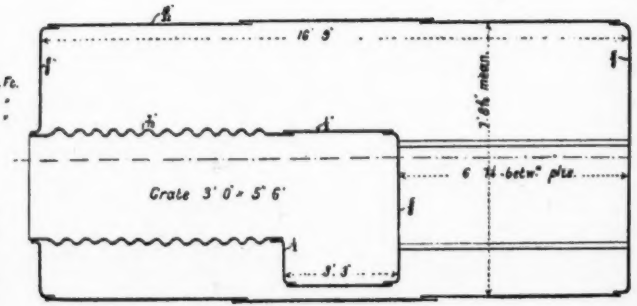




H.M.S. "THRUSH".

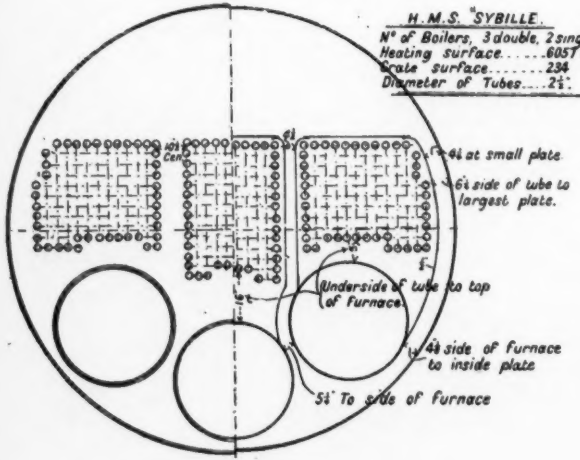
Boilers N°	2
Tubes N°	422
Tube surface	1824 Sq. Ft.
Total heating surface	2106 " "
Grate surface	32·5 " "
Diameter of Tubes	2½"

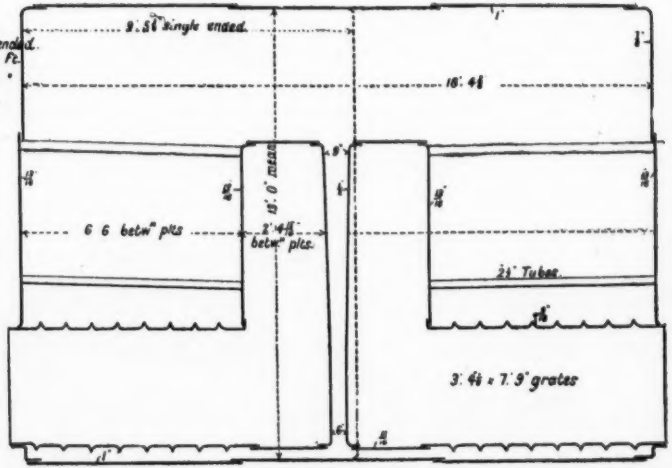


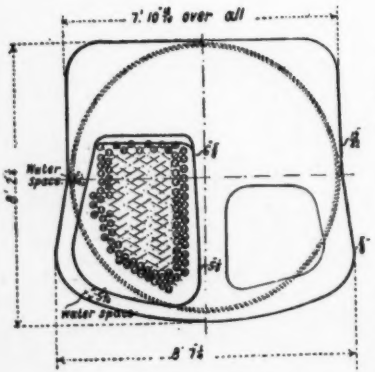


H.M.S. "SYBILLE."

N° of Boilers, 3 double, 2 single ended.
Heating surface.....6057 Sq Ft.
Grate surface.....234 " "
Diameter of Tubes....2½".

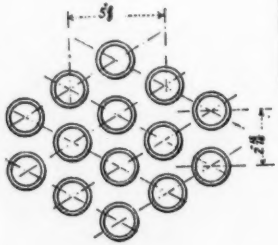

4½ at small plate
6½ side of tube to largest plate.
Underside of tube to top of Furnace
4½ side of furnace to inside plate
5½ To side of furnace

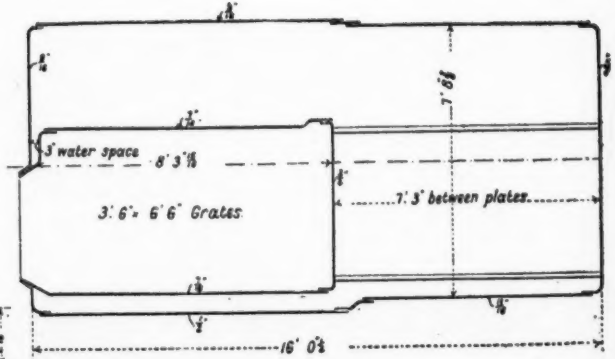


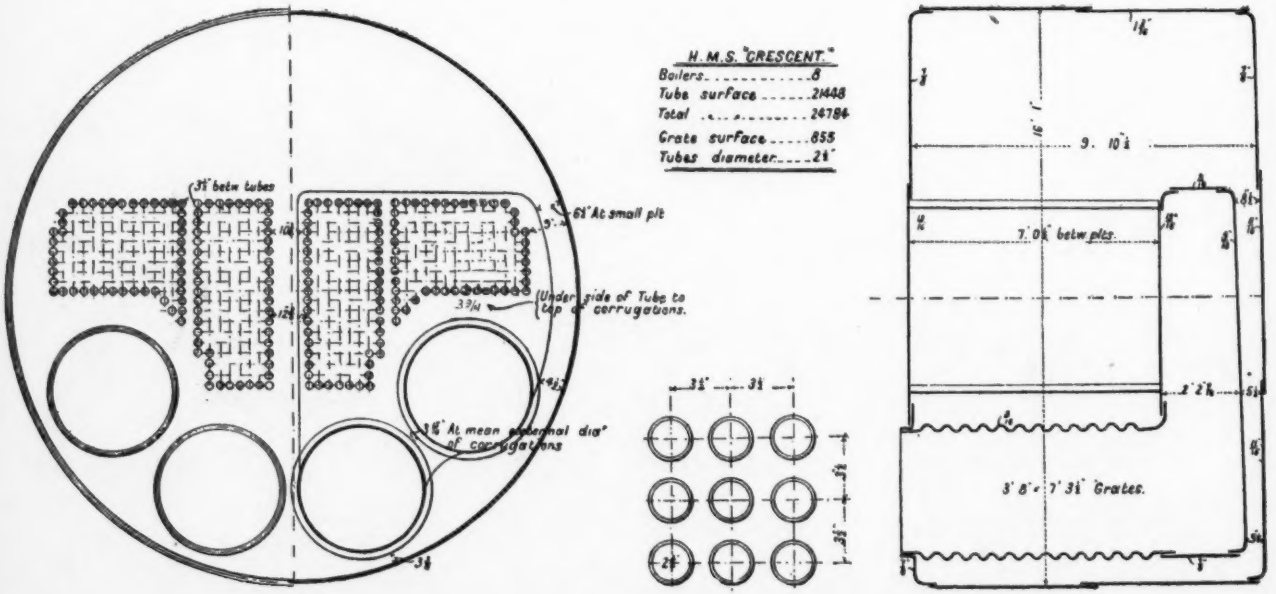


H.M.S. "JASON".

Boilers	4 Nº
Tubes Nº	1448.
diameter	2"
surface	5297
Total surface	6388
Grate surface	472







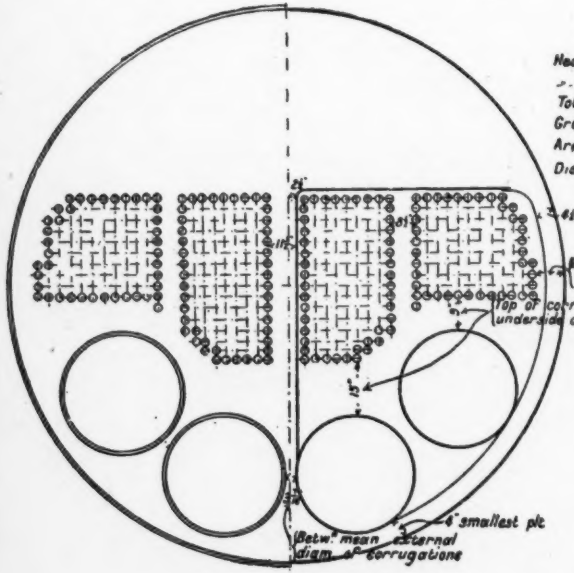
H. M. S. "CRESCENT."

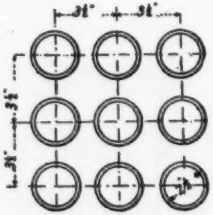
Boilers	6
Tube surface	21448
Total	24784
Grate surface	855
Tubes diameter	2¼"

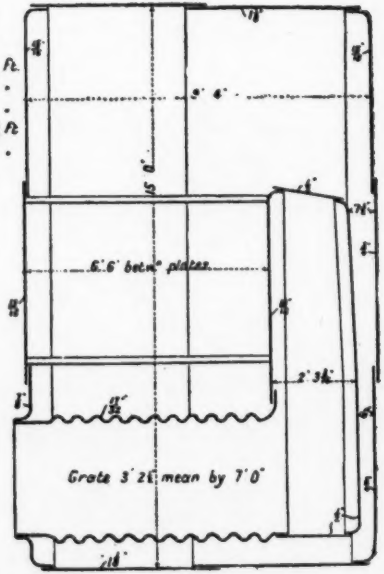
H.M.S. "ROYAL SOVEREIGN."

PARTICULARS FOR 8 BOILERS.

Heating surface in Tubes	17016 sq Ft.
" " Furnaces &c	3018 " "
Total Heating surface	20034 " "
Grate surface	718.6 sq Ft
Area through tubes	97.6 " "
Diameter of tubes	2½"


4½ smallest plate
6½ side of tube to smallest plate
Top of corrugation to underside of tube
6" smallest pit
Betw.n mean external diam.s of corrugations

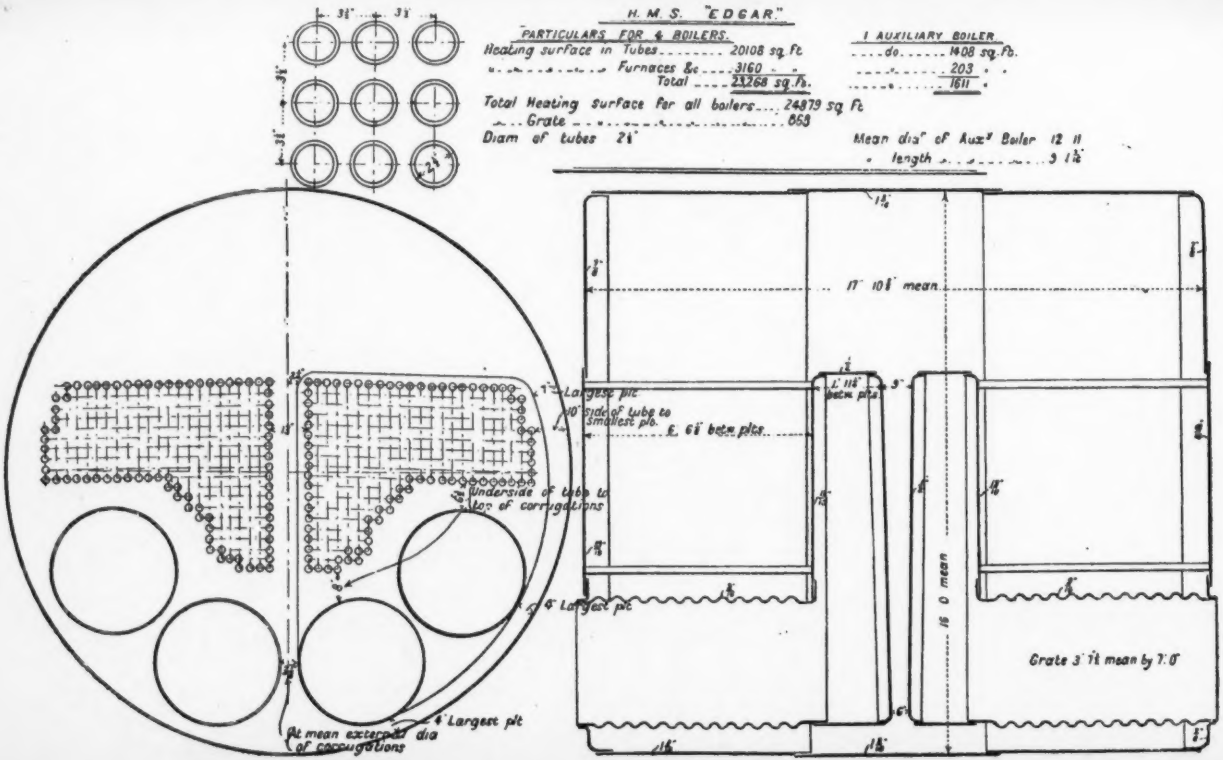




H. M. S. "EDGAR"

PARTICULARS FOR 4 BOILERS

1 AUXILIARY BOILER


H. M. S. "EDGAR."
PARTICULARS FOR 4 BOILERS.
Heating surface in Tubes ..... 20108 sq. Ft
" " Furnaces &c ..... 3160 "
Total ..... 23268 sq. Ft.
Total Heating Surface for all boilers ..... 24879 sq. Ft
Grate 863
Diam of tubes 2¼"
1 AUXILIARY BOILER
do ..... 1408 sq. Ft.
" ..... 203 "
..... 1611 "
Mean dia" of Aux" Boiler 12 11
" length 3 1½
3½" 3½"
3½"
3½"
2¾"
Largest plt
10" side of tube to smallest plt.
6⅝ betw plts.
Underside of tube to top of corrugations
4" Largest plt
Ft mean exterior dia of corrugations
4" Largest plt
17' 10½" mean
1' 11⅛" betw plts
16' 0" mean
Grate 3' 7½" mean by 7' 0"

nections should be fitted from the auxiliary feed pumps to enable them to circulate the water in the boilers.

The Committee take types of boilers fitted in various classes of ships. Amongst the battleships, they select as typical the boilers of the *Royal Sovereign*, *Barfleur*, *Hercules* and *Monarch*. In the first-class cruisers, the *Edgar* and *Crescent* are instanced; in second-class cruisers, the *Latona* and *Hermione;* in the single-screw gunboats, vessels of the *Thrush* class; and in the torpedo gunboats the *Jason* and *Halcyon*. The boilers of all these vessels are considered suitable for naval service, but remarks are made with a view of indicating what are considered to be the relative merits of the various types of boilers fitted. Boilers of battleships which are of the four-furnace, single-ended, return-tube type, may be divided into three classes, according to arrangement of combustion chambers. Thus, the *Royal Sovereign* and *Hercules* have two combustion chambers; the *Resolution* and *Revenge* have a separate combustion chamber for each furnace, and the *Royal Oak* has three combustion chambers for four furnaces. Of these three types the Committee consider one combustion chamber to each furnace to be the best, by which we conclude it is meant that the balance of advantages, taking all points into consideration, lies with the separate combustion chamber. That, of course, would be the logical deduction from the unqualified statement made. The Committee also prefer the separate combustion chamber in cruiser boilers. The three-furnace boilers, either single or double-ended, having separate combustion chambers, as fitted in the second-class cruisers, are considered suitable boilers. The Navy boilers, with two furnaces, as fitted in the *Thrush* class, would also be considered satisfactory, although some members of the Committee believe it would be better to have a separate combustion chamber to each furnace. The torpedo gunboats of the *Jason* class are fitted with wet-bottom locomotive boilers, having divided furnaces. This type is considered to be suitable for the requirements of such vessels.

Although a general preference is expressed for separate combustion chambers, the double-ended boiler, with combustion

chambers common to each pair of opposite furnaces, is looked on as an efficient type. For greater subdivision of power, single-ended boilers are to be preferred where the extra weight can be allowed. Three-furnace boilers are stated to be superior to those of four furnaces, supposing the extra space required can be given. Indeed, four-furnace boilers should only be placed in ships in which the limitation of the floor space occupied by the boilers is so important as to necessitate the employment of very large boilers, in which three furnaces, if fitted, would be too large in diameter. In dealing with the return-tube boiler, the Committee consider that an amount of total heating surface equal to about $2\frac{1}{2}$ square feet per indicated horse power at natural draft should be provided, whilst an area of grate surface equal to about $\frac{1}{33}$ of the total heating surface is recommended. In regard to steam space, the present practice of the Admiralty is considered satisfactory.

For the Navy type boilers, as fitted in sloops and gunboats, it is stated that the present practice as regards heating surface and steam space at natural-draft power is satisfactory. In the torpedo-gunboat type of boiler a total heating surface of about 2.5 square feet per indicated horse power at natural draft is recommended, and the present practice as regards steam space and grate area is considered satisfactory. As regards water spaces, other than those between adjacent tubes, it is considered that these might, with advantage, be somewhat increased from the sizes which in many recent cases have been fitted. The boilers of the *Crescent*, the *Thrush* and the *Jason* are referred to as satisfactory.

The question of the tube arrangement next receives attention. Tubes $2\frac{1}{2}$ inches in diameter outside, with a thickness of 0.16 inches, and a distance apart in a vertical direction of 1 inch, for the return-tube and Navy type of boilers, are considered satisfactory. As regards the distance apart in a horizontal direction, an increase is considered desirable. This distance is recommended to be not less than $1\frac{1}{8}$ inches. The diameter, thickness, and distance apart of the tubes in the *Jason* boilers are said to be such as will give good results. The report states that "a

large combustion chamber is advantageous," and in return-tube boilers the combustion chamber should generally be not less than 2 feet 3 inches wide for separate combustion chambers, and 4 feet for double-ended boilers with combustion chambers common to the opposite furnaces. In boilers of large size this width might, with advantage, be further increased. In the Navy type boilers the present combustion chambers of about 3 feet 3 inches long are satisfactory. In the *Jason* boilers the distance between tube plate and grate end is sufficient.

With boilers designed as above recommended, the Committee consider that the specified forced-draft power should be limited to 25 per cent. above the specified natural-draft power in the case of return-tube and Navy boilers; whilst 40 per cent. increase may be allowed with the torpedo gunboat type. In return-tube and Navy boilers the length of grate should not exceed twice the internal diameter of the furnace, whilst the end of the grate should be 6 inches from the combustion chamber. Steel tube plates from $\frac{5}{8}$ inch to $\frac{13}{16}$ inch thick are recommended for combustion chambers, the former being preferred, if the staying can be arranged to suit this thickness. Steel tubes, it is stated, corrode and pit more rapidly than those of iron; but as the former can be removed, stretched and replaced, the preference is given for mild steel. It is recommended that experiments should be made in order to ascertain the desirability of fitting spiral retarders in the tubes, or of using Serve ribbed tubes, or possibly a combination of both. It is also recommended that experiments should be made to settle authoritatively the merits of the closed ashpit system, as against the closed stokehold, and the Committee also recommend the fitting of tubulous boilers in two vessels for experimental purposes.

In connection with this matter an important expression of opinion is given. "It is considered," the report says, "that only those tubulous boilers that are fitted with straight tubes of comparatively large diameter, arranged so as to be readily cleaned and examined, should be considered as suitable for trials, with a view, if found satisfactory, to their being fitted to the larger class of warships." Having regard to the importance of

the subject, the Committee would recommend that these experiments be made without delay, so that data may be obtained for guidance as to the adoption or otherwise of this type of boiler. In view, however, of the requirements of the larger vessels, they further recommend that one at least of any new cruisers should be arranged to receive tubulous boilers, should the trials proposed prove satisfactory. The Committee also recommend that the *Speedy*, which will probably be launched from Messrs. Thornycroft's yard in a few days, should be thoroughly tried as soon as possible, to determine if boilers constructed with small tubes are suitable for continuous service at sea.

The main report is signed by the chairman, Admiral Buller; Mr. John H. Heffernan, Mr. J. T. Corner and Mr. James T. Milton. Mr. Heffernan is a well-known Navy engineer, who has long occupied a prominent position in the service. Mr. Corner is the chief engineer of Portsmouth Dockyard, and Mr. Milton, we need hardly state, is the chief engineer-surveyor at Lloyd's. There are three minority reports; the first by Mr. W. Castle, who concurs with the main report, excepting in regard to the recommendations which contemplate a reduction of power obtained from a given weight of boilers. He considers that the boilers of the *Latona* class, as now designed, have given satisfactory results. The maximum power for the present weight of boilers would, however, according to the proposals of the Committee, be reduced from 9,000 to less than 7,000 indicated horse-power. This, he says, appears unnecessary. He is of opinion that the boilers of the *Royal Sovereign* class are large enough for the maximum power of 13,000 horse, provided the boilers are fitted with ferrules. He also considers that the double-ended boiler, with opposite furnaces common, is a superior type to that with separate combustion chambers, and that the double-ended boiler with one common combustion chamber, as in the *Vulcan*, is an efficient type. Mr. Castle evidently pins his faith to the Admiralty ferrule.

Mr. Peter Samson, who represents the Board of Trade, also fully concurs with the Committee's report, but maintains that Navy boilers should be tested at twice the intended working pressure.

Mr. Manuel, the well-known engineer of the P. & O. Company, also gives a supplementary report; his dissensions from the main report being, in addition to that already referred to with regard to piston speed, "that for the required full power on emergencies, bearing surfaces of journals and crankshafts and connecting rods should be increased in the intermediate and low-pressure engines up to 8 per cent., according to the relative proportion of power and weights under which those journals work; that the main shafts, more especially crankshafts, have too much material bored out of the center. * * * Engine beds and framing might be increased with advantage 6 per cent." Mr. Manuel also considers that the cylindrical shells and main longitudinal stays in the boilers of the *Royal Sovereign* are not sufficiently strong. The former should be increased 10 per cent. and the latter 15 per cent., whilst the hydraulic test should be $1\frac{3}{4}$ times the intended working pressures. He would not approve of the four-furnaced boiler under forced draft, but would substitute a three-furnace boiler, with furnaces of from 3 feet to 3 feet 8 inches in diameter. He also recommends "that the furnaces have separated combustion chambers, and where weight and space are limited for double-ended boilers, that a common combustion chamber to two opposite furnaces is preferable and practicable, as in use in the fast and hard-driven mail steamers in the Atlantic service, both with natural draft and closed stokehold and forced heated air draft" The locomotive type of boiler, with forced draft, Mr. Manuel does not consider suitable for torpedo gunboats in rough weather, the Navy type being more suitable for rough weather conditions. He recommends, however, tubulous boilers, with tubes rising diagonally or slightly curved, for vessels of this class, provided the feeding arrangements are reliable. He considers that the present practice under forced draft should be the minimum capacity, and could be increased in some cases with advantage. Water spaces round $2\frac{1}{2}$-inch tubes under forced draft should not be less than $1\frac{1}{4}$ inches; and that the specified forced-draft power should not exceed 10 per cent. above the natural-draft power in return-tube and Navy boilers, and 15 per cent. in torpedo-boat boilers, but

in tubulous boilers may be increased to 40 per cent., and under these conditions the higher powers required in the service can be maintained at sea. The length of grate should not exceed 6 feet or less with high forced draft. The furnaces should not be less than 7 feet 6 inches in length, increasing in proportion to the diameter of the furnace, and the end of the grate bars should not be less than 10 inches from the end of the furnace. Good iron tubes, Mr. Manuel thinks, are most suitable, and retarders are essential under forced draft for 2½-inch tubes and upwards. Finally, Mr. Manuel is of opinion that the closed ashpit system, using heated air, has further advantages than those mentioned—amongst them, less risk of leakage, ease in working, and greater economy; whilst cold air pressures from closed stokeholds are liable to severely affect the intensely heated surfaces of combustion chambers and tube plates. In cases where tubulous boilers are used, the feeding arrangements should be of a thoroughly reliable character.

We have summarized the latter part of the report somewhat briefly, giving merely the opinions expressed; limitations of time and space at our disposal have both prompted us to this course. We shall, however, return to a further consideration of the matter at a future date.

THE CONTRACT TRIAL OF THE U. S. S. *NEW YORK.*

By Passed Assistant Engineer E. R. Freeman and Assistant Engineer M. A. Anderson, U. S. Navy.

The *New York* is a twin-screw armored cruiser, and was built and equipped ready for service by the Wm. Cramp & Sons Ship and Engine Building Company, of Philadelphia, Pa., the designs throughout having been furnished by the Navy Department. The contract price was 2,985,000 dollars, and the requirement as to speed was that the vessel should maintain a speed of 20 knots for four consecutive hours with an air pressure in the fire rooms not exceeding 2½ inches, it having been further stipulated that a premium of 50,000 dollars should be paid to the contractors for every quarter knot made in excess of this requirement, and that a penalty of 50,000 dollars should be exacted from them for every quarter knot deficiency.

The ship is divided into 184 water-tight compartments, and there is a double bottom 3 feet 6 inches in depth amidships, divided into eleven water-tight compartments, and extending from frame 27 to frame 81, and about 29 feet outboard at the midship section. There is also a coffer dam on each side outboard, 3 feet 6 inches wide, between the protective and berth decks, extending the entire length of the ship. Aft of the machinery spaces the coffer dams extend up only about half way to the berth deck. The coffer dams are filled with cellulose. There are fore-and-aft passages on each side, one 2 feet wide next the coffer dams, and one 4 feet wide below the protective deck underneath the coffer dams, and both extending the entire length of the machinery spaces. Both passages are divided up by water-tight bulkheads, and together with the coffer dams form practi-

cally an extension of the double bottom, as the bottoms of the lower passages are the tops of the outboard extremities of the double bottom. In effect the double bottom is further extended by water-tight compartments forward and aft beneath the ram plate and steering-engine flats, which serve also as trimming tanks.

For pumping and draining there is a 14-inch main pipe on the port side, and a $7\frac{1}{2}$-inch secondary pipe on the starboard side, extending from the forward boiler compartment to the after engine compartment. Each of these pipes has a branch in each engine and boiler room leading to its own cistern, and fitted with a screw-down non-return valve operated from above the protective deck. In the forward boiler room and after engine rooms there are valve boxes connected with these drainage pipes and with the compartments outside of the machinery spaces. There are six pumps in the engine rooms connected with both the main and the secondary drainage pipes, one pump in each fire room connected with the secondary pipe, and there is a wrecking pump in each auxiliary fire room connected with the main pipe. Each main circulating pump is also connected with that pipe. A suction manifold in each forward engine room is connected with the double-bottom compartments, and with two pumps in each of those engine rooms and with one pump in each after engine room. The double-bottom compartments are fitted with vent pipes led well up above the level of the berth deck, and can be flooded through the suction manifold above mentioned from sea valves in the forward engine rooms. All valves, however, in suction pipes leading to the compartments are non-return unless lifted beyond a certain point. All compartments above the double bottom and outside the machinery spaces communicate with those compartments containing the drainage cisterns through sluice valves, which are worked from the berth deck in all cases except the lower bunkers and wing passages abreast the engine rooms. Those valves are worked from the engine and fire rooms.

There are 63 coal bunkers, two tiers of 10 each on each side and one midship bunker above the protective deck, and one tier

of 11 on each side below the protective deck. Their total capacity in tons of 42 cubic feet is 1,279.66. The bunkers can be filled either through adjustable chutes which deliver into the inboard upper bunkers from the spar deck, or through coaling ports on the berth deck which deliver into the outboard upper bunkers and into the passages. There are hinged sections of the protective deck underneath the coaling ports for filling the lower bunkers. The coal in the upper bunkers is struck below through these openings in the protective deck. There are elaborate overhead trolleys throughout the bunkers.

There are no outside ash chutes, the ashes being discharged through inside pipes which lead down from the gun deck near the side and pass through the side near the berth deck.

ARMOR.

The protective deck, which extends the entire length of the ship, is constructed of two courses of 1½-inch mild steel. Over the machinery spaces it is reinforced with an additional course of 3-inch nickel steel. Around the engine hatch there are also glacis plates, rising three feet above the protective deck flat, and inclined at an angle of about 30 degrees. There is a belt of 4-inch nickel steel, 8 feet 10 inches wide, on the sides abreast the machinery spaces. The armor on the sponsons of the 6-pounders is 2-inch nickel steel. That on the sponsons of the 4-inch guns is 4-inch nickel steel. That on the sponsons of the 8-inch broadside guns is 2-inch nickel steel. On the barbettes of the turrets there are 10-inch nickel steel plates, and on the turrets 5½-inch nickel steel plates. The conning tower and shield are made of 7½-inch and the tube of 5-inch nickel steel. There are two steel military masts, each having three fighting tops. The turrets and barbettes are supported by a structure of cylindrical and radial vertical plates, built up from the gun deck, below which the weight is taken by stanchions and bulkheads, extending down to the protective deck. There is a boom on each mast, and a crane on each side of the spar deck, in the waist, for handling boats, anchors, etc. In addition to the usual direct communication by voice tubes and electrical annunciators between

the conning tower and the various parts of the ship, there is a central station interposed.

ARMAMENT.

There are two 8-inch guns mounted in the forward turret, two in the after turret, and one in a sponson on each side of the spar deck in the waist. There are six 4-inch and four 6-pounder R.F. guns mounted in sponsons on each side of the gun deck, and two 1-pounder and two Gatling guns mounted in each of the two lower tops on each mast. Riflemen will be stationed in the upper tops. There are five torpedo tubes, one discharging dead ahead, one on each bow, and one on each quarter.

HULL.

Material	Mild steel.
When built	1890–1893.
Length between perpendiculars	380 feet.
Length on L.W.L.	380 feet.
Length over all (including rudder)	384 feet.
Beam extreme	64 feet 3 inches.
Beam at L.W.L.	64 feet 3 inches.
Ratio of length to beam	5.98
Draught, mean, sea-going trim	24 feet.
Displacement, sea-going trim (load draught)	8,529
Displacement per inch at L.W.L.	39.5 tons.
Area of immersed midship section, sea-going trim	1,365 square feet.
Area of L.W.L. plane	16,600 square feet.
Center of gravity of L.W.L. plane aft of midship section	3.6 feet.
Center of buoyancy above base	14 feet ¾ inch.
Center of gravity above base	22.57 feet.
Center of buoyancy aft of midship section	1.04 feet.
Transverse metacenter above center of buoyancy	13 feet 11 inches.
Longitudinal metacenter above center of buoyancy	310 feet 10 inches.
Coefficient of fineness on extreme dimensions	.509
Coefficient of fineness on immersed midship section	.575
Coefficient of fineness of L.W.L.	.679
Wetted surface	30,814.49 square feet.

MAIN ENGINES.

There are four vertical, direct-acting, three-cylinder, triple-expansion engines, placed one in each of four separate water-tight compartments, connected by five water-tight doors, one on each side in the athwart ship bulkhead, one in the fore-and-aft bulkhead between the forward compartments, and two in the fore-and-

aft bulkhead between the after compartments. All these doors are on a level with the working platform. The starting gear is inboard.

The distinguishing feature of the *New York's* main engines is that there are two engines on each shaft, and that the forward ones can be disconnected so that the after ones may be used under economical conditions when reduced speed of ship is desired. The disengaging couplings, fitted for this purpose, are located in the after engine rooms, and can be operated from either the forward or after rooms.

The I.P. and L P. cylinders are fitted with steam jackets, and the H.P. cylinder with a working lining. The valves are all of the single-ported piston type, made of cast iron, one for the high and two each for the intermediate and low-pressure cylinders. The low-pressure valves are balanced by making the upper ends larger in diameter than the lower, the live steam being between the ends. The other valves are fitted with balancing pistons, connected above with the condensers. The valve gear is of the double-bar Stephenson link type. The cut-off can be varied by means of a slot in the reversing arm. The reversing gear is what is known as the Cramp Steam Reversing Gear, and consists of a steam-lift secured to one of the engine frames, and connected to an arm on the reversing shaft. The lifting piston is operated by a piston valve which is controlled by a floating lever, receiving motion at one end from the hand lever, and a reverse motion at the other from the reversing arm, so that the piston moves and stops when the hand does. The diameter of the reversing cylinders is 14 inches, and the stroke 19 inches. The reversing gear of both engines on one shaft can be operated by one lever in either engine room, or at the door between the engine rooms; or either forward or after hand lever may be disconnected from the others. Each engine has a detachable hand reversing gear, which consists of a hand wheel, worm shaft, pinion and rack attached to a separate arm of the reversing shaft.

Each engine is fitted with a disc stop valve, having a screw stem and a balancing piston, and a butterfly throttle. The

former is 12⅜ inches diameter, and the latter 14 inches. The main pistons are of cast steel dished, and fitted with two packing rings, each ⅝-inch wide and ¾-inch deep, also the followers are grooved. The crank and wrist pins are fitted with slab brasses, the former brasses as well as the eccentric straps being lined with Parson's white metal. The eccentric straps are made of composition. The crossheads are of forged steel, bolted to cast-steel shoes, faced with Parson's white metal. The engine frames are of the inverted Y type and made of cast iron, two for each cylinder. The frame which forms the go-ahead guide is covered for water circulation. The bed plates are made of cast steel, each in three sections, bolted together. The exhaust passages between the steam chests and to the condensers are all formed by external composition pipes. There is a copper expansion joint next to the condenser in each main exhaust pipe.

The main steam pipes, which are made of copper, are reinforced with iron bands at intervals of six inches.

A distributing oil tank is placed over each forward engine, supplied by a horizontal, duplex Blake pump, and fitted with a glass gauge and overflow pipe. Both the supply and distributing pipes of these tanks are fitted with glass filters. From the distributing pipes branches lead to manifolds on each cylinder of each engine. The manifolds are fitted with adjusting valves and glass sights, from which tubes are led to the various bearings, journals, guides, etc. There is also a steam connection for blowing through the lubricating system.

The main engine stop valves and the main boiler stop valves and safety valves can be operated from the berth deck.

Number of cylinders (each engine)		3.
Diameter of H.P. cylinder	All engines	32 inches.
Diameter of I.P. cylinder	All engines	47 inches.
Diameter of L.P. cylinder	All engines	72 inches.
Stroke of all pistons		42 inches.
Diameter of H.P. valve (one for each cylinder)		16 inches.
Diameter of I.P. valves (two for each cylinder)		16 inches.
Diameter of L.P. valves (two for each cylinder),	Top	31 inches.
	Bottom	29½ inches.

Area of H.P. steam ports for maximum opening,	Top	95.95 square inches.
	Bottom	104.32 square inches.
Area of I.P. steam ports for maximum opening (two valves)	Top	202.1 square inches.
	Bottom	220.95 square inches.
Area of L.P. steam ports for maximum opening (two valves)	Top	392.35 square inches.
	Bottom	401.25 square inches.
Area of H.P. exhaust port for maximum opening	Top	151.51 square inches.
	Bottom	129.16 square inches.
Area of I.P. exhaust port for maximum opening (two valves)	Top	303.02 square inches.
	Bottom	248.46 square inches.
Area of L.P. exhaust ports for maximum opening (two valves)	Top	503.83 square inches.
	Bottom	508.84 square inches.
Area of main steam pipe (12 inches diameter)		113.1 square inches.
Area of main exhaust pipe (24.5 inches)		471.43 square inches.
Volume swept by H.P. piston per stroke, mean		19.143 cubic feet.
Volume swept by I.P. piston per stroke, mean		41.764 cubic feet.
Volume swept by L.P. piston per stroke, mean		98 551 cubic feet.
Clearance of H.P. cylinder, per cent	Top	20 32
	Bottom	20.11
Clearance of I.P. cylinder, per cent	Top	20.49
	Bottom	19.80
Clearance of L. P. cylinder, per cent	Top	11.44
	Bottom	9.89
Ratio of net area of H.P. to I.P. pistons		2.207
Ratio of net area of I.P. to L.P. pistons		2.373
Ratio of net area of H.P. to L.P. pistons		5.237
Diameter of piston rods		6¼ inches.
Length of connecting rods between centers		84 inches.
Diameter of connecting rods		6¼ and 9 × 6¼ inches.

Shafting and Bearings.—The shafting is steel throughout. The couplings are fitted with tapered, headless bolts, and split-pins over the nuts. The crank shaft for each engine is in three sections, and the sequence of cranks is H.P., I.P., L.P. There is a short line shaft between the after section of the forward crank shaft and the forward section of the after one. On the after end of the line shaft is fitted the disengaging coupling, which is constructed as follows: On the after end of the line shaft and the forward end of the forward section of the after crank shaft there are flanges, 2 feet 8 inches in diameter, and 5½ and 3½ inches thick, respectively, which are exactly similarly cogged to a depth of 4 inches. There are eight cogs on each flange, 6½ inches wide at the points, and extending across the flanges. A steel

sleeve, 3 feet 2 inches outside diameter, 2 feet 8 inches inside diameter, and 10 inches long, is grooved inside to mesh on the cogs of the shaft flanges when in position. The sleeve is moved by two screws on opposite sides, working in eyes on a recessed, loose collar. The go-ahead faces of the cogs are fitted with steel liners $1\frac{1}{8}$ inches thick. The planes of all the faces of the cogs, if extended, would be tangent to a 3-inch axial cylinder. The thrust shaft is coupled to the propeller shaft in the following manner: A tapered socket is forged on the thrust shaft, fitted with a feather key, and receives the tapered end of the propeller shaft, on which a collar is screwed up against and secured to the face of the socket with eight tap bolts. Keepers are fitted on the heads of the bolts and forcing screws in the collar for starting the propeller shaft. The propeller shafts are in two sections, and are cased only in the bearings and stern tubes. They are protected by zinc strips where the casings end and where the brass covers of the outboard couplings touch them. These covers are also tinned all over.

The crank-shaft bearings have only bottom brasses, the caps being extended down to take the place of the top brasses. The whole bearing, top and bottom, is lined with Parson's white metal. The thrust bearing is of the horse-shoe collar type, and is lined with Parson's metal. The pedestal is formed into an oil trough with an adjustable bearing at each end, and with stuffing boxes for confining the oil. Pipes are led through the oil bath, through which cooling water may be circulated.

Diameter of crank shaft	Forward	$13\frac{1}{2}$ inches.
	Aft	17 inches.
Length of H.P. crank shaft	Forward	86 inches.
	Aft	92 inches.
Length of I.P. crank shaft		112 inches.
Length of L.P. crank shaft		86 inches.
Diameter of crank pins	Forward	$13\frac{1}{2}$ inches.
	Aft	$14\frac{1}{4}$ inches.
Length of crank pins		17 inches.
Width of crank web	Forward	15 inches.
	Aft	$18\frac{1}{2}$ inches.
Thickness of crank web	Forward	9 inches.
	Aft	$11\frac{1}{2}$ inches.

Diameter of flanges of crank shaft	Forward	25½ inches.
	Aft	30½ inches.
Thickness of flanges	Forward	3 inches.
	Aft	4 inches.
Number of coupling bolts (one flange)	Forward	7.
	Aft	9.
Diameter of coupling bolts	Forward	2¾ inches.
	Aft	3 inches.
Diameter of hole in crank shaft	Forward	6 inches.
	Aft	7 inches.
Diameter of hole in crank pins	Forward	6 inches.
	Aft	7½ inches.
Total length of crank-shaft bearings (each engine),	Forward	80 inches.
	Aft	70 inches.
Diameter of line shaft		13½ inches.
Length of line shaft (1 section)		64 inches.
Diameter of hole in line shaft		6 inches.
Diameter of flanges		25½ inches.
Thickness of flanges		3 and 5½ inches.
Number of bolts in one flange		7.
Diameter of bolts		2¾ inches.
Diameter of thrust shaft		16 inches.
Length of thrust shaft		21 feet.
Diameter of hole in thrust shaft		7½ inches.
Diameter of flanges		30½ inches.
Thickness of flanges		4 inches.
Number of bolts in each flange		9.
Diameter of bolts		3 inches.
Number of thrust collars		12.
Diameter of thrust collars		24 inches.
Diameter of shaft in thrust bearing		16¾ inches.
Actual thrust surface		1828.8 square inches.
Thickness of thrust collars		2 inches.
Space between collars		4 inches.
Diameter (outside) of socket on thrust shaft		29 to 32 inches.
Diameter (inside) of socket on thrust shaft		15½ to 16¾ inches.
Depth of socket		22½ inches.
Thickness of screw collar on propeller shaft		6½ inches.
Diameter of collar bolts		2¾ inches.
Number of collar bolts		8.
Diameter of propeller shaft,	Forward section	16¾ inches.
	After section	17½ inches.
Length of propeller shafts	Forward section	28 feet.
	After section	41 feet 10 inches.
Diameter of hole in propeller shaft		7½ inches.
Diameter of hole in shaft in propeller hub		4 inches.

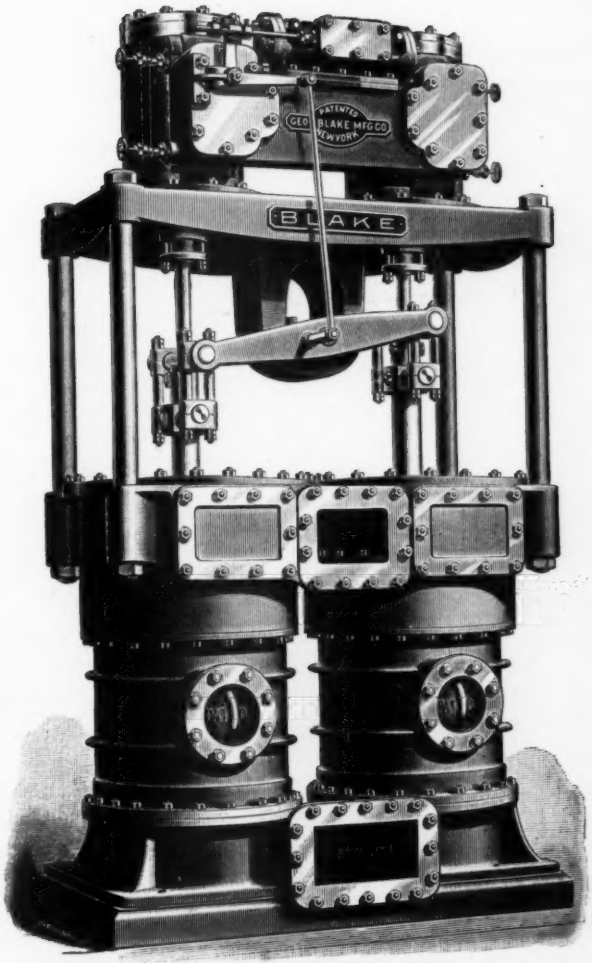
Thickness of composition shaft casing,	At bearings	1⅛ inches.
	Elsewhere	½ inch.
Length of casing in stern bearing		18 feet.
Length of casing in bracket bearing		7 feet 4 inches.
Length of bearings in stern tubes...	Forward	2 feet 11½ inches.
	Aft	3 feet 6 inches.
Length of bracket bearings		5 feet 1¾ inches.

Main Condensers.—The main condensers, one for each engine, are made of cast brass, each in five sections, including the water chests. The water circulates through tubes.

Length over all	10 feet 9 inches.
Diameter of shell, inside	5 feet 9 inches.
Thickness of shell	½ inch.
Length of tubes exposed	9 feet.
Diameter of tubes outside	⅝ inch.
Thickness of tubes, B.W.G., No. 20	.035 inch.
Number of tubes, one condenser	3,776.
Cooling surface, one condenser	5,560 square feet.
Ratio of cooling surface of 4 condensers to H.S. of 6 boilers	1 to 1.394

Air Pumps.—There is one double, vertical, single-acting Blake air pump for each main engine, fitted with the Blake valve gear. Both pumps on either side are connected with both condensers on the same side with intervening straightway valves, and exhaust into either the exhaust main or the I.P. or L.P. valve chests. The pumps are connected by a beam pivoted at its center. The beam receives its motion through links swinging from a crosshead on the pump and piston rods at each end. (See annexed cut.) The operation of these pumps has proved most satisfactory, even at as low a speed as nine double strokes per minute.

Diameter of steam cylinders (two)	12 inches.
Diameter of water cylinders (two)	25 inches.
Stroke	18 inches.
Diameter of piston rods	2¼ inches.
Diameter of pump rods	4 inches.
Number of foot valves (rubber) each pump cylinder	10.
Diameter of foot, bucket and delivery valves	5½ inches.
Area of valves, each	13 square inches.
Number of bucket valves	8.
Number of delivery valves	8.
Ratio of volume swept by L.P. piston, per stroke, to that of air-pump buckets, per stroke	9.64



Air Pump of U. S. Cruiser "New York."

Circulating Pumps.—There is a centrifugal circulating pump for each condenser, arranged to draw either from the sea, from the bilge of its engine room, or from the main drainage pipe. The sea and bilge injection valves are fitted with a safety lock, so that both cannot be open at the same time. The circulating pumps are driven by horizontal, simple, single-cylinder, direct-acting engines.

Diameter of steam cylinders	12 inches.
Stroke	6 inches.
Diameter of runner	32 inches.
Diameter of suction	14 inches.
Diameter of discharge	14 inches.

Screw Propellers.—The propellers are made of manganese bronze, and are three-bladed, true screws. The blades are adjustable, and bent back through an angle of about 22 degrees. The hubs are spherical, and fitted with conical tail-pieces.

Number of blades	3.
Diameter of propeller	16 feet.
Diameter of hub	54 inches.
Length of hub	43 inches.
Pitch, as set on trial	21 feet.
Helicoidal area for one screw	69.09 square feet.
Projected area for one screw	56.57 square feet.
Disc area for one screw	201.06 square feet.
Ratio, pitch to diameter	1.3125
Ratio, disc area of two propellers to area of immersed midship section	.297
Immersion of center of propeller at draught of 26 feet ½ inch aft	10 feet 6 inches.

Speed Indicators.—In each after engine room there is a mechanical device for indicating the speed of both main shafts. Each indicator is fitted with two indices pivoted at the center of a graduated disc, and connected by shafting and gearing, one to the starboard and the other to the port main shaft. The pointers are so geared that they have a much slower speed than the main shafts, and the graduations on the disc are numbered for revolutions of the main shafts, so that the number of graduations traversed by the indices per minute indicates the speed of the engines. The indices are also so arranged that they can be

set together at any time, and in that way the relative speed of the two engines can be quickly and accurately ascertained. There are similar mechanical direction indicators, one for each shaft, located on the bridge. Electrical speed indicators and speed telegraphs have also been fitted in the engine rooms, on the bridge and at the after end of the superstructure, but they have not proved satisfactory.

BOILERS.

There are six double-ended, cylindrical, horizontal, fire-tube main boilers with four Fox corrugated furnaces in each end, and two single-ended, horizontal, fire-tube auxiliary boilers with two furnaces in each. The main boilers are located, two each, in three water-tight compartments, separated by two athwart-ship bulkheads. There is one smoke pipe for each pair of boilers. The auxiliary boilers are located on the protective deck and over the two after pairs of main boilers, the uptakes of each end of which pass over and join each other above the auxiliary boiler. The smoke pipes of the auxiliary boilers pass up through the centers of the main smoke pipes.

The longitudinal shell seams of the main boilers are treble-riveted with double butt straps. The circumferential seams are lapped and treble-riveted. The front and back heads of the auxiliary boilers are curved at the top; those of the main boilers are flat. The furnaces are fitted with patent rocking cast-iron grate bars and bearers. There are 7 grate bars in each furnace of the main boilers, each extending the whole length of the furnace, and each weighing 157 pounds. They rock on lugs on the front and back bearers and on projections on the middle bearers, and can be easily renewed without hauling fires. These bars withstood forced draft most satisfactorily.

The jackets of both main and auxiliary smoke pipes and uptakes are extended down to the uptake doors, where they are fitted with slide shutters for ventilation when not under forced draft. The smoke pipes are oval in shape. The boilers are fitted with a steam-circulating apparatus, and the internal feed pipes are arranged to distribute the feed water throughout the boilers.

MAIN BOILERS.

Length ..... 18 feet.
Diameter, outside ..... 15 feet 9 inches.
Number of furnaces ..... 8.
Diameter of furnaces, outside ..... 43 inches.
Diameter of furnaces, inside ..... 39 inches.
Length of grates ..... 76 inches.
Outside diameter of tubes ..... 2¼ inches.
Length of tubes between sheets ..... 78 inches.
Spacing of tubes horizontally ..... 3½ inches.
Spacing of tubes vertically ..... 3¼ inches.
Number of common tubes ..... 844.
Number of stay tubes ..... 304.
Thickness of common tubes, No. 12, B.W.G. ..... .109 inches.
Thickness of stay tubes, No. 6, B.W.G. ..... .203 inches.
Total number of tubes in one boiler ..... 1,148.
Number of combustion chambers ..... 4.
Depths of combustion chambers ..... 24⅜ and 25⅜ inches.
Width of combustion chambers ..... 7 feet.
Thickness of shell plates ..... 1 3/4 1/4 inches.
Thickness of heads ..... Top ..... 1 inch.
Bottom ..... ¾ inch.
Thickness of tube sheets, front and back ..... ⅝ inch.
Thickness of combustion-chamber plates ..... 9/16 inch.
Thickness of furnaces ..... 7/32 inch.
Diameter of rivets in longitudinal seams ..... 1¼ inches.
Diameter of rivets in circumferential seams ..... 1¼ inches.
Pitch of screw stays ..... 7 inches.
Diameter of screw stays ..... 1 7/16 inches.
Number and diameter of through braces above tubes ..... 4 ..... 2¾ inches.
27 ..... 2½ inches.
Number and diameter of braces to back tube sheet ..... 8 ..... 2 inches.
6 ..... 1¾ inches.
Number and diameter of braces around lower manhole ..... 3 of 1¾ inches.
Tube heating surface, one boiler ..... 4,395.11 square feet.
Plate heating surface ..... 772.47 square feet.
Total heating surface ..... 5,167.52 square feet.
Grate surface ..... 164.66 square feet.
Area through tubes ..... 24.63 square feet.
Area over bridge walls (eight) ..... 10.44 square feet.
Area through uptake ..... 16 square feet.
Volume of furnaces and combustion chambers above grates ..... 522.4 cubic feet.
Steam room, water six inches above tubes ..... 857.42 cubic feet.
Water surface, water six inches above tubes ..... 252.7 square feet.
Diameters of smoke pipes ..... 8 feet 6 inches by 6 feet 6 inches.
Area of smoke pipe (two boilers) ..... 46.18 square feet.

Height of smoke pipe above lowest grates..... 80 feet.
Diameter and number of safety valves in one case..... 4 of 4 inches.
Load on safety valves..... 160 pounds.
Diameter of main boiler stop valves..... 10 inches.
Diameter of auxiliary boiler stop valves..... 5 inches.
Diameter of auxiliary stop valves on main boilers..... 7 inches.

Totals for six main boilers:

Tube heating surface..... 26,370.66 square feet.
Plate heating surface..... 4,634 46 square feet.
Total heating surface..... 31,005.12 square feet.
Grate surface..... 987.96 square feet.
Area through tubes..... 147.78 square feet.
Area over bridge walls..... 62.64 square feet.
Area through uptakes..... 96 square feet.
Area of water surface..... 1,516.2 square feet.
Volume of steam room..... 5,144.52 cubic feet.
Volume of furnaces and combustion chambers above grates... 3,134.4 cubic feet.
Weight of boilers with fittings and water, per 100 square feet of heating surface..... 2.22 tons.

Ratios:

Tube H.S. to G.S..... 26.69 to 1.
Plate H.S. to G.S..... 4.69 to 1.
Total H.S. to G.S..... 31.34 to 1.
Area through tubes to G.S..... .149 to 1.
Area of water surface to G.S..... 1.53 to 1.
Steam room, per square foot G.S..... 5.2 cubic feet.
Volume of combustion chambers and furnaces above grates and bridge walls, per square foot of G.S..... 3.172 cubic feet.

Totals for two auxiliary boilers:

H.S..... 1,952.68 square feet.
G.S..... 64 square feet.
Weight of auxiliary boilers (two) with fittings and water..... 48.56 tons.
Ratio of total G.S. to H.S. (all boilers)..... 1 to 31.33.

Forced Draft.—The closed fire room system of forced draft is used. For this purpose there are provided fourteen blowers, one at each end of each main boiler, and one in each auxiliary fire room. The fans are driven by enclosed, double-cylinder, vertical, simple engines, with cranks set opposite each other, and using but one valve. There are no air locks for hoisting ashes under forced draft.

BLOWERS IN MAIN FIRE ROOMS.

Diameters of steam cylinders	5 inches.
Stroke	4 inches.
Diameter of fans	5 feet.
Width of fans	19 inches.

BLOWERS IN AUXILIARY FIRE ROOMS.

Diameter of steam cylinders	3½ inches.
Stroke	2½ inches.
Diameter of fans	3 feet.
Width of fans	16 inches.

Feed Pumps.—There are two vertical, duplex, double-acting Blake pumps in each fire room, one for main and one for auxiliary feed. Both the main and auxiliary feed pumps are so connected that any pump will supply any boiler, but there is no connection between the main and auxiliary systems. There are also independent connections with the feed tanks. Two of the engine room pumps are connected with the feed tanks and main feed systems. These pumps are also arranged to draw from the channel pipes of the main condensers. The main feed pumps draw from the feed tanks only, and deliver to the boilers only. The auxiliary feed pumps draw from the tanks, the bilge, the secondary drains, the boilers and the sea, and deliver into the boilers, the fire main and overboard. The dimensions of the feed pumps in the main fire rooms are: Steam cylinders, 12 inches; water cylinders, 7 inches; stroke, 12 inches. The dimensions of those in the auxiliary fire room are: Steam cylinders, 6 inches; water cylinders, 4 inches; stroke, 7 inches.

Auxiliary Condensers.—There is a Wheeler condenser in each after engine room, both of which are connected with the auxiliary exhaust system. The tubes are arranged and packed as in the ordinary condensers. Attached to each of these condensers is a combined, horizontal, air and circulating pump, all the pistons on one rod, and the steam pistons between the water pistons. The dimensions are:

Cooling surface, one condenser	1,360 square feet.
Diameter of air pump cylinder	10 inches.
Diameter of circulating pump cylinder	10 inches.
Diameter of steam cylinder	8 inches.
Stroke	12 inches.

Feed Tanks.—There is in each forward engine room a feed tank of a capacity of about 1,700 gallons each. The tanks are fitted with an overflow valve and sight funnel, an automatic valve in the internal suction nozzle, and perforated partitions for the application of filtering material. There are also grease extractors in the main feed pipes of each pair of boilers. These extractors are similar to large Macomb strainers, the basket or perforated internal chamber being filled with filtering material, and by-pass valves and pipes and hinged cover bolts, being provided to facilitate overhauling.

Steam Traps.—The separators, radiators, jackets, steam coils in the ship's coppers, the steam tables in the pantries, and the drains of the main and auxiliary steam pipes are fitted with traps.

Other Auxiliary Machinery.—In each forward engine room there is a vertical duplex double-acting Blake pump, 14 × 9 × 12, which draws from the feed tanks, main condensers, sea, bilges, main and secondary drainage pipes and compartments, and delivers into the boilers, overboard and to the fire main. In each engine room there is a vertical duplex double-acting Blake pump, 12 × 7 × 12, which draws from the crank-pits, bilges, sea, main and secondary drainage pipes and indirectly from the compartments, and delivers into the fire main and overboard. In each after engine room there is a vertical duplex double-acting Blake pump, 8 × 5 × 12, which draws from the sea and delivers into the water-service pipes and the fire main.

In each forward engine room there is a double-cylinder vertical, simple engine, cylinders 7 inches and stroke 6½ inches, secured to the after bulkhead, for turning the main engines. It operates on a worm wheel on the line shaft through bevel gears and a worm. The worm is made to slide on a feather key, and is held in place by a collar below and a removable key above it. A double-pawl ratchet is fitted to the shaft of this engine for turning by hand.

In each fire-room hatch there is a self-controlling, double-cylinder, simple vertical engine, cylinders 4½ inches and stroke 4½ inches, for hoisting ashes. In the after part of the ship below the

protective deck there is a self-controlling, double-cylinder, horizontal, simple engine, cylinders 13 inches, stroke 10 inches, for operating the steering gear. It is geared to a horizontal fore-and-aft shaft, on the after end of which is a right-and-left hand screw. The screw works in eyes in two crossheads, one on the port and one on the starboard side. The crossheads are connected by rods to the ends of the rudder yoke. In the engine-room hatch above the protective deck are two ventilating blowers for engine-room service only. There are four similar blowers on the berth deck abreast the middle-boiler hatch, two on the port and two on the starboard side, for ventilating the ship generally, and are arranged to exhaust or supply air. They are all operated by engines similar to those of the forced-draft blowers, and their dimensions are: Diameter of cylinders, 4 inches; stroke, 3 inches; diameter of fans, 4 feet; width of fans, 19 inches. On the spar deck there are four two-cylinder horizontal, 8 × 7-inch and two 8 × 8-inch winch engines. On the gun deck, forward, is a two-cylinder vertical, 12 × 14-inch windlass engine. Each turret is turned by a two-cylinder horizontal engine, 11½ × 10 inches, secured overhead beneath the protective deck. These engines are controlled by a piston-reversing valve, which can be operated both from the sight hoods and at the engines. The valve gear is arranged as in Cramp's reversing gear, so that the distribution valves of the cylinders come back to midgear and shut off the steam when the hand wheel is stopped.

There is a vertical single-cylinder engine, 4 by 5 inches, for operating the power tools in the workshop. The workshop is located in the after magazine passing room. In the fourth fire room from forward on each side is a two-cylinder, oscillating engine, 5 × 6 inches, for operating the ammunition hoists of the broadside 8-inch guns. The hoists are endless chains fitted with racks, which carry the ammunition. At the top of the hoists the ammunition is automatically detached from the racks and held. The chains of the turret hoists carry loading cars.

Distilling Apparatus.—There are two horizontal coil evaporators and two distillers, capable of furnishing 10,000 gallons of potable water in twenty-four hours. The evaporators are connected

with the condensers as well as the distillers. The circulating water for the distillers is supplied by a horizontal, single-cylinder pump 7 × 8 × 10 inches, and after leaving the distillers passes into the flushing pipes. There are by-pass valves and pipes for turning this water directly into the flushing pipes. There is a double horizontal, single-cylinder pump, 3½ and 2 × 2 × 4 inches, one cylinder of which feeds the evaporators and the other delivers the water from the distillers to the tanks.

The ship is supplied with a compressed air deck sweep. There are steam connections with the bunkers for extinguishing fire.

Ice Machine.—On the starboard side of the berth deck, forward, is a dense-air ice machine which is capable of furnishing one ton of ice per day. The refrigerating room is on the gun deck above the ice machine.

Dynamos and Motors.—There are two dynamos of 80 volts and 400 amperes capacity, and one of 80 volts and 200 amperes capacity, located forward of the forward fire room. They are directly connected to the shafts of vertical, two-cylinder, simple engines, 13 × 6 inches and 8½ × 6 inches, and at full load have a speed of 400 revolutions. There are 491 (16 c.p.) and 230 (10 c.p.) incandescent lights and 50 additional outlets. There are four (50,000 c.p.) projectors and five search light mounts. The four ammunition hoists of the forward and after magazines are operated by motors. Those for the 4-inch guns are about four horse power each, and those for the 8-inch about six each.

The ship will be furnished with a number of telephones and electric drills, and an electric gig capable of making about 8 knots for four hours.

WEIGHTS.

Propelling machinery, including water	1,529.5 tons.
Reciprocating parts:	
H.P. piston	794 pounds.
I.P. piston	1,426 pounds.
L.P. piston	3,006 pounds.
Piston rods	2,670 pounds.
Crossheads	3,015 pounds.
Connecting rods	3,233 pounds.

TRIAL.

The official trial took place on May 22, 1893, off the coast of New England, between Cape Ann and Cape Porpoise. The conditions as to sea and wind were most favorable, and the ship made a mean speed of 21 knots. The machinery operated most satisfactorily in every respect, except that a slight stream of water was required on the wrist pins of the forward starboard H.P. engine. Indicator diagrams were taken every half hour from each main cylinder, and once an hour from the main air and circulating pumps. Both auxiliary condensers were in use and received the exhaust of all the auxiliaries, except the main air and circulating pumps, which exhausted into the main condensers. All main and auxiliary boilers were in use and under forced draft. The coal used was hand-picked Pocahontas.

DATA OF TRIAL.

Draught at beginning	Forward 22 feet. Aft. 26 feet 1 inch.	24 feet ½ inch.
Draught at end	Forward 21 feet 6 inches. Aft. 26 feet.	23 feet 9 inches.
Draught mean for trial	Forward 21 feet 9 inches. Aft. 26 feet ½ inch.	23 feet 10¾ inches.
Displacement at mean draught on trial		8,480 tons.
Area of immersed midship section		1,350 square feet.
Wetted surface		30,814.49 square feet.
I.H.P. (total) per 100 square feet of wetted surface		56.47.
I.H.P. per 100 square feet of wetted surface at 10 knots in ratio of 3.5 power		4.21.
Average speed		21 knots.
Slip (mean of both screws)		24.48 per cent.
Speed $^3\times$ area immersed midship section $\div$ I.H.P.		732.76
Speed $^3\times$ displacement $^{\frac{2}{3}}\div$ I.H.P.		226.204

SYNOPSIS OF STEAM LOG.

	Starboard.		*Port.*
Revolutions of main engines per minute	134.65		135.
Revolutions, mean of both engines		134.82	
Piston speed, feet per minute	942.55		945.
Steam at boilers (gauge)		175.7	
Steam at engines (gauge)	168.6		169.9
Steam at first receiver (absolute)	70.02		68.7
Steam at second receiver (absolute)	27.5		27.6
Vacuum in condenser, in inches of mercury	25.3		25.5
Opening of throttle in tenths	2.15		2.65

		Starboard.		*Port.*
Steam cut off in fraction of stroke from beginning	H.P.	.70		.70
	I.P.	.71		.71
	L.P.	.71		.71
Double strokes of air pump per minute		16 5		14.8
Revolutions of circulating pump per minute		170.1		165.3
Temperatures in degrees Fahrenheit,	Steam at H.P. cylinder	369.8		336.3
	Injection		46.	
	Discharge	107.		111.8
	Hot well		101.3	
	Feed		129.4	
Revolutions of blowers per minute,	Main boilers		578.5	
	Auxiliary boilers		433 5	
Air pressure in inches of water	Main firerooms		2.02	
	Auxiliary firerooms		.7	
H.P cylinder, forward	Mean pressure	59.1		58.6
	I.H.P.	1,328.03		1,318.78
H.P. cylinder, aft	Mean pressure	61.1		57.5
	I.H.P.	1,372.86		1,295.27
I.P. cylinder, forward	Mean pressure	28.6		28.4
	I.H.P.	1,398.73		1,392.09
I.P. cylinder, aft	Mean pressure	28.1		27.4
	I.H.P.	1,369.46		1,342.46
L.P. cylinder, forward	Mean pressure	13.6		12.6
	I.H.P.	1,568.33		1,459.77
L.P. cylinder, aft	Mean pressure	13.8		12.9
	I.H.P.	1,598.24		1,503.27
Aggregate equivalent mean pressure on L.P. piston		37.4		35.85
Collective I.H.P. of each main engine,	Forward	4,295.09		4,170.64
	Aft	4,340.56		4,141.00
Collective I.H.P. of both main engines		8,635 65		8,311.64
Collective I.H.P. of all main engines			16,947.29	
I.H.P. of air pumps (two each side)		22.26		16.48
I.H.P. of circulating pumps (two each side)		20.00		19.48
Collective I.H.P. of air and circulating pumps (four each)			78.21	
I.H.P. of all forced-draft blowers (14)			236.24	
I.H.P. main feed pumps (3)			49.53	
I.H.P. of two combined auxiliary air and circulating pumps			3.14	
I.H.P. other auxiliaries			87.03	
Collective I.H.P. all auxiliaries			454.13	
Collective I.H.P. each main engine, air and circulating pump	Forward	4,318.03		4,190.01
	Aft	4,359.62		4.157.84
Collective I.H.P. both main engines, air and circulating pumps		8,677 65		8,347.51
Collective I.H.P. all main engines, air and circulating pumps			17,025.50	

	Starboard.		*Port.*
Total I.H.P. of all machinery in use		17,401.42	
Indicated thrust (I.H.P. main engines)	100,782.43		96,749.21
Indicated thrust per square foot of developed area of propeller	1,458.71		1,400.33
Indicated thrust per square inch of surface of thrust bearing	55.10		52.92
Velocity of steam, in feet per second, through the ports at at the maximum opening of the valves :			
H.P. steam ports, Top	131.66		132.00
H.P. steam ports, Bottom	116.47		116.77
I.P. steam ports, Top	134.90		135.26
I.P. steam ports, Bottom	121.16		127.48
L.P. steam ports, Top	163.01		163.44
L.P. steam ports, Bottom	158.19		158.60
H.P. exhaust ports, Top	83.38		83.60
H.P. exhaust ports, Bottom	94.08		94.32
I.P. exhaust ports, Top	89.93		90.17
I.P. exhaust ports, Bottom	107.6		107.69
L.P. exhaust ports, Top	126.		126.33
L.P. exhaust ports, Bottom	124.74		125.07
Main steam pipe	111.69		111.98
Main exhaust pipe	136.04		136.17
Cubic feet swept per minute by L.P. piston per I.H.P. of main engines, Forward	6.17		6.38
Cubic feet swept per minute by L.P. piston per I.H.P. of main engines, Aft	6.11		6.42
Square feet total cooling surface per I.H.P.		1.35	
Square feet total H.S. per I.H.P.		1.89	
I.H.P. of all machinery in operation per square foot G.S.		16.54	
I.H.P. per ton of propelling machinery, boilers and water,		11.37	

MAXIMUM PERFORMANCE SECOND HALF HOUR.

Revolutions of main engines per minute	133.7		134.5
Revolutions, mean, of both engines		134.1	
Piston speed per minute	935.9		941.5
Steam at boilers, per gauge		177	
Steam at engines, per gauge	170		170
Steam at first receiver, absolute	70.7		69.7
Steam at second receiver, absolute	28.7		26.
Vacuum in condenser	26		26
Opening of throttle, in tenths	2¼		2.
Steam cut-off, in fraction of stroke from beginning, H.P.		.70	
Steam cut-off, in fraction of stroke from beginning, I.P.		.71	
Steam cut-off, in fraction of stroke from beginning, L.P.		.71	
Double strokes of air pump per minute	13.6		11.5
Revolutions of circulating pump per minute	182.		174.

			Starboard.		*Port.*
Temperature in degrees Fahrenheit,	Steam at H.P. cylinder		370.		369.
	Engine room			80.	
	Injection			46.	
	Discharge	Forward	112.		116.
		Aft	100.		114.
	Hot well		105.		98.
	Feed			129.	
Revolutions of blowers				581.	
Air pressure in fire rooms, in inches of water				1.6	
H.P. cylinder,	Mean pressure	Forward	60.81		60.07
		Aft	61.		57.7
	I.H.P	Forward	1,360.56		1,365.90
		Aft	1,366.29		1,298.50
I.P. cylinder,	Mean pressure	Forward	28.9		28.3
		Aft	28.5		27.
	I.H.P	Forward	1,409.30		1,389.60
		Aft	1,393.48		1,352.59
L.P. cylinder,	Mean pressure	Forward	13.6		12.9
		Aft	14.3		13.2
	I.H.P	Forward	1,567.07		1,461.37
		Aft	1,636.24		1,533.45
Aggregate equivalent mean pressure on L.P. piston		Forward	37.37		36.42
		Aft	37.76		35.6
Collective I.H.P. each main engine		Forward	4,336.87		4,216.87
		Aft	4,396.01		4,184.54
Collective I.H.P., both main engines			8,732.88		8,401.41
Collective I.H.P., all main engines				17,134.29	
I.H.P. of air and circulating pumps			38.06		35.47
Collective I.H.P. air and circulating pumps				73.53	
I.H.P. of all other auxiliaries in operation				598.05	
Collective I.H.P. of all auxiliaries in operation				671.58	
Collective I.H.P. of both main engines, air and circulating pumps			8,770.94		8,436.88
Collective I.H.P. of all main engines, air and circulating pumps				17,207.82	
Total I.H.P. of main engines and all auxiliaries in operation				17,605.87	
Cubic feet swept per minute by L.P. piston per I.H.P.		Forward	6.12		6.35
		Aft	6.05		6.39
Square feet of total H.S. per total I.H.P					1.82
I.H.P. of all machinery in operation per square foot of G.S.				16.56	
I.H.P. per ton of propelling machinery, boilers and water				11.53	

It will be observed that there is an apparent anomaly in the data of the maximum performance, the revolutions being less

than the average for the whole four hours. An investigation of this led to the discovery that the data for another period in the trial showed the same anomaly, and, furthermore, that during these two periods the ship passed over the same part of the course. The anomaly was then very reasonably explained by the fact that the depth of water at this particular part of the course (as made by the ship) was from fifteen to twenty fathoms less than elsewhere. Thirty-seven fathoms was the depth, according to the chart, at this part. As the next ship to be tried draws the same amount of water that the *New York* does, and is reasonably expected to make two knots more speed, it seems that it would behoove the contractors to run her trial trip in water of considerably greater depth than thirty-seven fathoms, or else insist upon the adoption of a system of speeding ships which can be used well off shore, and which, furthermore, is not subject to fatal and very possible interruption by other vessels, as is the measured-course method.

The quantity of coal used on the official trial could not be ascertained with any degree of accuracy, nor could the amount of refuse from the coal used on the coal-consumption trial be ascertained satisfactorily.

COAL CONSUMPTION TRIAL.

On May 24th, while the *New York* was returning to Philadelphia, both forward engines were disconnected, and for eight consecutive hours the after ones only were used. At the time only the four after main boilers were in use, and without blowers. Both auxiliary condensers were also in use, and received the exhaust of all the auxiliary machinery, except the main air and circulating pumps which exhausted into the main condensers.

DATA OF THE COAL CONSUMPTION TRIAL.

Draught mean for the trial	22 feet 3 inches.
Displacement	7,700 tons.
Area immersed midship section	1,230 square feet.
Wetted surface (Kirk's system)	28,688 square feet.
I.H.P. per 100 square feet wetted surface	15.53
Average speed by one Cherub log	15.73 knots.
Slip, mean, per cent	16.53

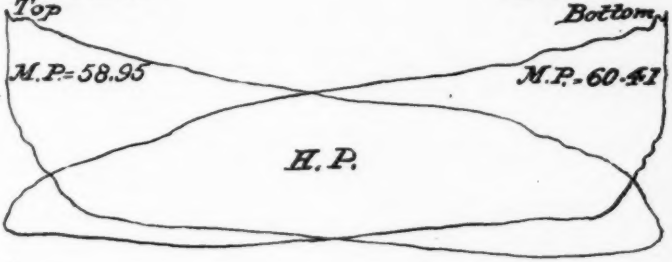
SYNOPSIS OF STEAM LOG.

		Starboard.	*Port.*
Steam at boilers (per gauge)			135.5
Steam at engines		134.4	131.9
Steam in first receiver (absolute)		44.1	44.9
Steam in second receiver (absolute)		17.4	19.7
Vacuum in main condensers in inches of mercury		26.	25.
Vacuum in auxiliary condensers		3.7	3.4
Cut-off	H.P.		.70
	I.P.		.71
	L.P.		.71
Revolutions		90.5	91.2
Throttle, tenths		1.	1.
Mean effective pressure	H.P.	48.3	45.8
	I.P.	20.6	27.
	L.P.	10.6	10.1
I.H.P.	H.P.	732.2	698.84
	I.P.	680.62	689.28
	L.P.	828.75	793.10
Total I.H.P. each engine		2,241.57	2,181.22
Total I.H.P. both main engines		4,422.79	
Air pumps		9.59	4.53
Circulating pumps		10.62	7.37
Collective I.H.P. each main engine, air and circulating pumps		2,261.78	2,193.12
Collective I.H.P. both main engines, air and circulating pumps		4,454.90	
Horse power of other auxiliaries in use		157.43	
Total horse power of all machinery in use		4,612.33	
Square feet of G.S. in use		658.64	
Square feet of H.S. in use		20,670.08	
Condition of vessel's bottom		Clean.	
Kind and quality of coal used		Picked Pocahontas.	
Net weight in pounds of fuel burned per hour		9,592.	
Pounds of fuel per I.H.P. per hour		2 08	
Pounds of fuel per square foot G.S. per hour		14.56	
I.H.P. per square foot of G.S.		7.00	
H.S. per I.H.P.		4 48	

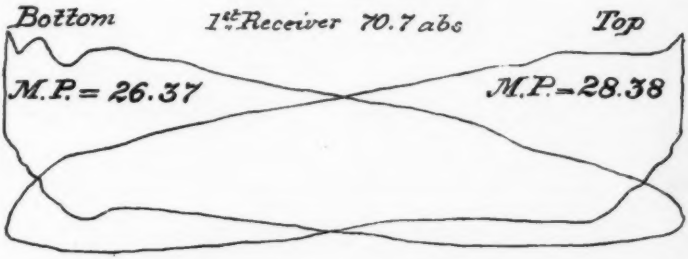
NOTE.—The indicator corrections reduced the I.H.P. 6.37 per cent. The I.H.P. quoted above in both trials is the corrected I.H.P.

U.S.S. New York.

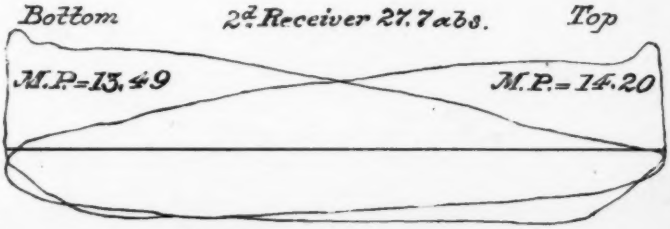
May 22d. 1893. 12.30 P.M.
Steam pressure at engines 171 lbs.
Revolutions per minute 131.
Vacuum 25.5 ins.



Scale = 80 lbs.



Scale = 40 lbs.



Scale = 20 lbs.

Air Pump Cards, U. S. S. New York.

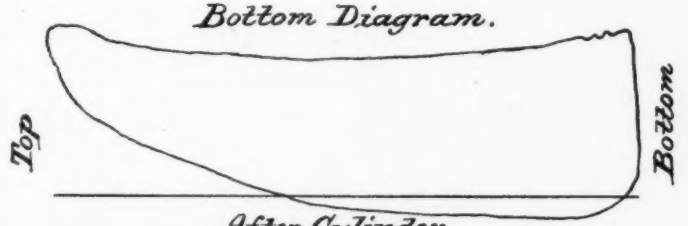
Taken on Preliminary Trial.

Steam pressure	168 lbs.
Double strokes	9½
Vacuum	24.2 ins.
Scale	80 lbs.

Forward Cylinder.

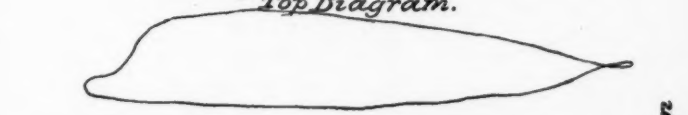
Top Diagram.

Bottom Diagram.

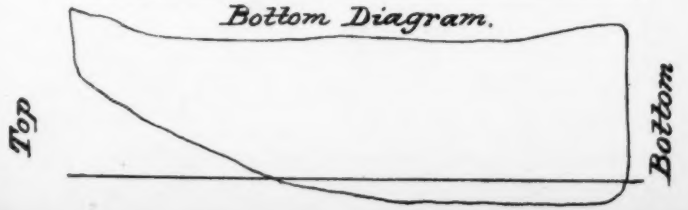


After Cylinder.

Top Diagram.



Bottom Diagram.



Air Pump Cards, U.S.S. New York.

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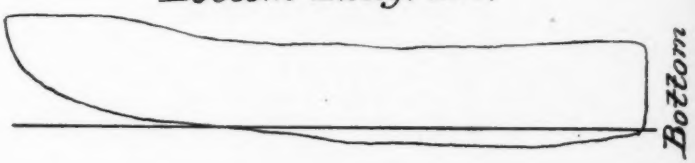
Double strokes	*9½*
Vacuum	*24.2 ins.*
Scale	*80 lbs.*

Forward Cylinder.

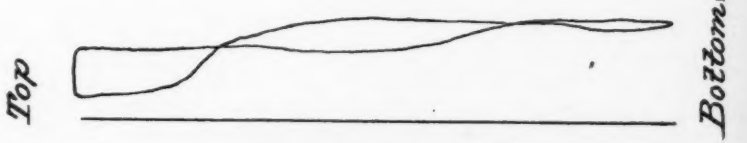
Top Diagram.

Bottom Diagram.

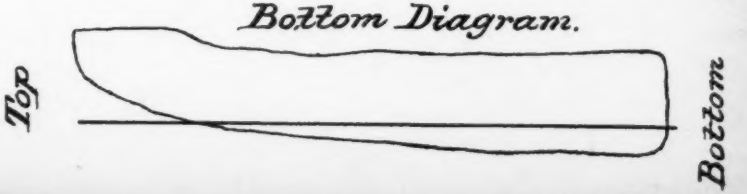


After Cylinder.

Top Diagram.



Bottom Diagram.



INTERNATIONAL ENGINEERING CONGRESS.

[Reprinted through the courtesy of the "Marine Review," of Cleveland, Ohio, from its issue of August 10th.]

Nearly every civilized nation was represented at the International Engineering Congress held at the Art Palace on the lake front in Chicago last week, and the assemblage of engineers, which has been looked to for some time past as one of the features of the World's Columbian Exposition, was truly the greatest ever witnessed in the world. As readers of the "Review" are most interested in the proceedings of the division of the marine and naval engineering and naval architecture, this account will be confined to the proceedings in that division, although it will be necessary to refer briefly to the opening general session of all the divisions.

The Hon. C. C. Bonney, president of the World's Congress Auxiliary, delivered an address of welcome, which was echoed by Mr. Octave Chanute, first vice chairman of the general committee of the International Engineering Congress. Addresses were also made by Sir Benjamin Baker of England, builder of the Forth bridge, Baron Quinette de Rochemont of France, C. O. Gleim of Germany, and several other distinguished foreigners, and also by the chairmen of the different divisions of the congress, namely: Mr. William Metcalf, division A, civil engineering; Mr. Eckley B. Coxe, division B, mechanical engineering; E. G. Spilsbury, division C, mining engineering; Henry M. Howe, division D, metallurgical engineering; Prof. Ira O. Baker, division E, engineering education; Major Clifton Comly, U.S.A., division F, military engineering, and Commodore Geo. W. Melville, U.S.N., division G, marine and naval engineering and naval architecture. The general meeting then adjourned, and the seven divisions of the congress opened sessions immediately afterward in the various halls.

MARINE AND NAVAL ENGINEERING AND NAVAL ARCHITECTURE.

About forty-five papers from the most distinguished representatives of the ship-building industry in Great Britain, Germany, Spain, Italy and the United States were contributed to the division of marine and naval engineering and naval architecture, and thirty-three of them were in print, while less than half a dozen of the whole number of papers put down on the programme failed of appearance. The foreign attendance was more than equal to that in other branches, and was fully up to what was expected in consideration of the diversified interests represented in the general congress. Among the eminent gentlemen in attendance at this branch of the congress may be mentioned General L. de Bussy, inspecteur général du génie maritime of France; Dr. Francis Elgar, of London, vice-president of the Institution of Naval Architects, and delegate from that institution to this congress; Colonel Nabor Soliani, of the corpo del genio navale of Italy; Commodore Alfred Dietrich, chief constructor Imperial German Navy; Professor Carl Busley, of the Imperial German Naval Academy at Kiel, Germany; Antonio de Barron Boneto, of the Brazilian Navy; M. Emile Bertin, directeur de l'écôle d'application du génie maritime, French Navy; M. Joseph Leflaive, ingenieur du corps du génie maritime, French Navy; Mr. James Howden, of Glasgow, inventor of Howden's system of forced draft; Commodore Melville, engineer-in-chief U. S. N., chairman of the division; Passed Assistant Engineer McFarland, secretary of the division; Commodore Charles H. Loring, U. S. N., formerly engineer-in-chief of the Navy; Geo. W. Dickie, Esq., manager of the Union Iron Works, San Francisco; Warren E. Hill, Esq., vice-president of the Continental Iron Works, Brooklyn, N. Y.; Naval Constructor Varney, U. S. N.; Geo. W. Street, assistant constructor U. S. N.; Chief Engineer David Smith, U. S. N.; Prof. W. F. Durand, of Cornell University, Ithaca, N. Y.; Prof. Ira N. Hollis, of Harvard University; Prof. H. W. Spangler, of the University of Pennsylvania; Col. E. A. Stevens, superintendent of the Hoboken Ferry Boat Company, New York; T. A. McElmell, Esq., superintendent of the Vacuum Oil Company, Rochester, N. Y.; Charles Ward, Esq., in-

ventor of the Ward water tube boiler, Charleston, W. Va.; Edward E. Roberts, of the Roberts Water Tube Boiler Company; H. B. Roelker, of No. 41 Maiden Lane, New York, proprietor of the Allen dense air ice machine; Charles W. Whitney, of New York City; Charles A. Moore, of the well-known firm of Manning Maxwell & Moore, Liberty street, New York; Asa M. Mattice, consulting engineer, of Cambridgeport, Mass.; Col. David P. Jones, chief engineer U. S. N., retired; John M. Sweeny, of Harvey, Ill.; Count de Balincourt, of the French navy; Passed Assistant Engineer Frank M. Bennett, U. S. N.; Chief Engineer John L. D. Borthwick, U. S. N.; J. R. Williams, mechanical engineer, No. 60 South Canal street, Chicago; Prof. John Pemberton, U. S. N., associate professor of mechanical engineering, Pennsylvania State College; Capt. Charles H. Manning, superintendent of the Amoskeag Mills, Manchester, N. H.; C. B. Calder, superintending engineer of the Mutual and Menominee steamboat lines, Cleveland; Joseph McMakin, superintending engineer Columbian Iron Works, Baltimore; Chief Engineer Kafer, U. S. N.; F. W. Grogan, architect of the naval exhibit of the World's Columbian Exposition; E. Platt Stratton, chief engineer surveyor, Record of American and Foreign Shipping, New York; C. D. Mosher, of No. 1 Broadway, N. Y.; Frank B. King, superintendent of the marine department, Maryland Steel Company, Sparrow's Point, Md.; Joseph R. Oldham, naval architect, Cleveland; Charles E. Fitch, No. 296 Elm street, Chicago; Alfred H. Raynal, Elizabeth, N. J.; E. N. Janson, bureau of steam engineering, Navy Department; P. A. Lennertz, mechanical engineer and naval architect; A. George Mattson, constructing engineer S. F. Hodge & Co., Detroit, Mich.; Henry C. Meyer, Jr., of the "Engineering Record," No. 227 Pearl street, New York; J. M. Mulrooney, of the "Marine Review"; Frank M. Dunlap, mechanical engineer, No. 57 Selden avenue, Detroit, Mich.; Theodore G. Hoech, royal Prussian inspector of waterways; D. W. Edmeston, of Clinton, Ill.; E. T. Sederholm, No. 1620 Fulton street, Chicago; H. F. Sillen; Assistant Engineer W. H. P. Creighton, U. S. Navy.

DISCUSSION OF PAPERS.

The first session began with an address by Commodore Melville, in which he expressed gratification at the large attendance, and welcomed the foreign guests. He then gave a brief summary of the present condition of matters connected with marine engineering and naval architecture, and sketched briefly the lines along which future progress will probably be made, calling special attention to the fact that it will most likely be on about the same lines as in the past, which have consisted of an increase of steam pressure, an increase of piston speed, better material, and, possibly, changes in design to a certain extent. He mentioned that experiments are now being made with steam of 1,200 pounds pressure, and called attention to the possibilities of the coil boiler for enabling great power to be obtained with little weight. He also mentioned in the course of his remarks the death of Dr. Alexander C. Kirk, a member of the advisory council of the division, who had begun a paper on the triple-expansion engine, and on which he was engaged at the time of his death.

The first paper was by Sir Nathaniel Barnaby, of England, on "The Best Ship of War." This was a paper worthy of its eminent author, and in brief compass contained the results of the experience of that eminent architect. This paper was discussed by Dr. Francis Elgar, of England; Chief Engineer Kafer, U. S. N.; Professor Durand, of Cornell University; Naval Constructor Varney, U. S. N., and several others. Other papers were by Mr. Lewis Nixon, superindending architect of Wm. Cramp & Sons' Ship and Engine Building Company, of Philadelphia, on "The New Vessels of the United States Navy," and "Naval Architecture in the United States," by Benjamin Martell, Esq., chief surveyor to Lloyds' Register. There was an interesting discussion of these papers, and several of the gentlemen expressed an intention to contribute remarks in writing in time to be published.

Dr. Francis Elgar, the distinguished English architect who comes to this congress as delegate from the Institution of Naval Architects, then read a paper on "The Present Condition of Naval Architecture." This was an eminently valuable paper,

and contained many points of the greatest interest. The doctor called special attention to the fact that, while at one time it may have been possible to design ships simply from experience gained by long practice, this no longer held, but the successful naval architect of to-day was the man who had and who must have a thoroughly scientific education as his basis. The meeting then adjourned, leaving several papers over for discussion at a subsequent date.

On Tuesday the first paper was "The Trireme at the Time of the Peloponnesian War," by Herr R. Haack, of Berlin, Germany, naval architect and formerly technical director of the Vulcan Iron Works. Although this paper is apparently of remote interest, it proved on reading quite the reverse, from the way in which it was treated, and the abstract which was read showed that the complete paper as it will appear in the proceedings will be of great interest. Two papers were then briefly discussed, the same being by General Casimiro de Bona, inspector general of engineers in the Spanish navy, on "Rossin's Method of Graphic Integration" and "Valve Diagrams." Next "The Relation of Speed and Power in Steamers," by Mr. Robert Mansel, the well known architect of Scotland, was discussed by Dr. Elgar, Professor Durand, Mr. McFarland and others. "The Use of Oil at Sea," by Mr. W. J. Millar, secretary of the Institution of Engineers and Shipbuilders in Scotland, was commended as an eminently valuable paper, containing much information, but there was no discussion of it.

"The Vibration of Steamers," by Herr Otto Schlick, consul of the Bureau Veritas at Hamburg, Germany, was a remarkably interesting paper, and elicited a valuable discussion. The discussion was by Mr. F. B. King, superintendent of the marine department of the Maryland Steel Company; Col. E. A. Stevens, superintendent of the Hoboken Ferry Company; Chief Engineer Kafer, Prof. Durand, Dr. Elgar, Mr. Oldham, Mr. Stratton, chief engineer surveyor of the Record of American and Foreign Shipping; Col. Nabor Soliani, of the Italian Navy; Naval Constructor Varney, U. S. N., and Mr. Alfred H. Raynal. In this liberal discussion a number of practical points of great interest were

brought out, among which was one by Dr. Elgar, that it has been found that when a ship is longer than twelve times her depth there is sure to be considerable vibration. Dr. Elgar also spoke of the recent experience of the builders of the big Cunard liner *Campania* with vibration in that ship, and related his personal observations on the subject during trial trips of the *Campania*. Unusual interest attended this discussion, on account of the subject being comparatively new in meetings of this kind, and Mr. Schlick, who has given a great deal of attention to the question of vibration, was highly complimented on the merits of his paper.

Then came a paper on "Welded Seams," by Mr. Warren E. Hill, vice president of the Continental Iron Works, which was also very interesting. In response to questions by gentlemen present, Mr. Hill gave additional information of great value. The discussion brought out the fact that a locomotive boiler without any riveted joints at all has been at work for the last four years, and has given entire satisfaction. Mr. Hill believes that in time, as people acquire the same confidence in welded seams as that now possessed by the manufacturers, riveted joints will disappear to a large extent.

The paper on "Screw Propulsion," by Mr. Sydney W. Barnaby, was discussed by Messrs. McFarland and Kafer, Col. Stevens, Messrs. James Howden, of Glasgow, H. B. Roelker and Dr. Elgar. This paper is certainly one of the most valuable that has been presented to the congress, and contains in short space practical rules which have been deduced from the extended experiments of Isherwood, Froude, Thornycroft, Yarrow and others.

"The Resistance of Ships," by Prof. Riehn, of Hanover, Germany, was a subject bristling with mathematics, but containing much valuable and interesting matter and information. The general opinion was that, as the paper had, unfortunately, been circulated but very recently in advance, a very valuable discussion could not be expected, and therefore none was made.

On Wednesday the first two papers were on the "Rules for Boiler Construction of Various Governments and Registration Societies," written by Nelson Foley, the manager of the Haw-

thorn-Guppy Company, of Naples, Italy, and the "Government Inspection of Merchant Vessels and the Influence Thereon of Registration Societies," by E. Platt Stratton, chief engineer surveyor to the Record of American and Foreign Shipping. These two papers are of entirely different character, that of Mr. Foley being strictly technical, and discussing the various rules for strength. It is a most valuable paper, and will be of the greatest value to marine engineers in the designing of boilers. Mr. Stratton's paper was less technical, but brought out an animated discussion, which was participated in by some fifteen or twenty of the gentlemen present. The fact was pretty thoroughly established that there is great dissatisfaction with the rules of the steamboat inspection service in this country, largely on account of the fact that they are not sufficiently elastic to provide for progress in marine engineering and ship building. The form of test piece for boiler material was pretty well discussed, and the present form condemned. The question of the factor of safety for steam boilers was also discussed, and several eminent gentlemen expressed the idea that the proposition in the Frye bill, of about a year ago, to have a factor of 5, was not desirable, as a lower factor would be entirely satisfactory. This idea, however, was combated very strongly by other gentlemen who had given the matter great attention.

A most valuable paper was that entitled "Auxiliary Machinery for War Vessels," by George W. Dickie, manager of the Union Iron Works, San Francisco, Cal. This paper is not only valuable for the splendid review of the subject, and the author's thorough grasp of it, but for his novel propositions in regard to several points. Mr. Dickie's immense experience as the manager of the Union Iron Works for so many years has enabled him to see the defects in existing methods, and he proposes in his paper certain other methods which would materially reduce the complication at present existing aboard ship, with an attendant increase in economy. This paper was discussed by Prof. Hollis of Harvard University, recently an engineer officer in the Navy, Mr. Asa M. Mattice, formerly of the engineer corps of the Navy, and now a prominent consulting engineer in Boston; Chief En-

gineer Kafer of the Navy, Col. E. A. Stevens and Mr. A. H. Raynal. To these remarks Mr. Dickie briefly responded. Two papers were then taken up on "Hydraulic Machinery for Maneuvering Guns," by Mr. A. A. Willson, superintending engineer of the Quintard Iron Works, New York City; and "Hydraulic Appliances in Boiler Construction," by Signor G. Migliardi, of the firm of Migliardi Bros., Italy. Both of these papers were of great interest, and received much commendation. They were discussed by Messrs. Raynal, Mattice and Dickie. The other papers on Wednesday's programme were then postponed until Thursday, and it was announced that an evening meeting would be held in order to consider the papers which were accompanied by lantern slides, or rather stereopticon views.

A PLEASANT EVENING MEETING.

The evening session was very much enjoyed and was largely attended. The first paper was by Prof. Durand, professor of marine engineering and naval architecture at Cornell University, on the "Planning and Equipment of a Modern Ship and Engine Building Plant." As this paper had been printed in advance, it was taken as read, and the professor occupied his time describing the splendid series of lantern slides illustrative of the powerful tools used in ship and engine building, as well as large cranes for handling the material, mast shears, and other similar appliances. Remarks were made on some of the tools and appliances at the Union Iron Works by Mr. Dickie, manager of that institution, a special description being given of the hydraulic lifting dock, which, from Mr. Dickie's description, seems to be an extremely efficient and economical structure, much more so than the ordinary graving docks. At the conclusion Prof. Durand was warmly complimented on the excellence of his paper and of the lantern slides. In the absence of Mr. Weir, the author of a paper on "Boiler Feed," Secretary McFarland gave descriptions of the lantern views accompanying the paper, Mr. Weir having provided a very complete description of them. These covered experiments in regard to corrosion in steam boilers and the progress of improvement in regard to devices for feed water heating for boilers. The slides included views of

the very latest devices of this kind, such as those on the *Campania* and Mr. Vanderbilt's yacht *Valiant*. The evening's entertainment concluded with a most interesting series of pictures of ice yachts, by Mr. Archibald Rogers, of Hyde Park on the Hudson, N. Y., the well-known enthusiast on yachting matters, and who has recently built one of the yachts which is to compete as possible defender of the America's cup this season. These views showed the standard forms of the ice yacht, together with some of the earlier types, as well as some beautiful views of winter scenery on the Hudson.

CLOSING DAYS OF THE CONGRESS.

At Thursday's session the papers receiving most attention were "Forced Draft," by James Howden, "Liquid Fuel on Steam Vessels," by Col. Soliani, and "Coil and Tubulous Boilers," by Charles Ward, builder of the tubulous boilers on the U. S. S. *Monterey*. The main feature of the discussion attending Col. Soliani's paper was with regard to danger of explosion, and in answer to a number of questions on this point the distinguished author expressed the opinion that there was no danger in using the refuse that remains after all of the illuminating and lubricating products of petroleum have been extracted. At present, on account of the high price and of the limited quantity available, petroleum refuse fuel, notwithstanding the many advantages that could be derived from it, cannot be adopted for general use on board ships, at least in the mercantile navy. In war ships its military advantages may lead even now to its partial adoption. The combustion of coal and petroleum refuse combined in the same furnaces gives an easy and simple means of securing, to a certain extent, the advantages of power that can be derived from oil fuel, without endangering the supply of fuel to the ships, as the coal arrangements on board are left unaltered. The combined combustion will therefore probably be the form in which the oil fuel will at first be applied to warships during the period of transition from coal to liquid fuel. It was also agreed that petroleum fuel might be kept in reserve for use in emergency where its advantages would overcome the question of cost.

Mr. Howden's paper on "Forced Draft" was considered in connection with that of Henry Benbow, chief inspector of machinery, British Navy, on "Effect of Forced Draft in Causing Leaky Boiler Tubes, and the Remedies Therefor." The inventor of the system of draft in use on the *New York* and *Paris* went so thoroughly into the subject in his paper that there was little room for extended discussion. Mr. Howden treated the engineers to considerable additional information in extended remarks, however, and after he had finished Mr. Dickie remarked that he noticed that the chairman (Engineer-in-Chief Melville, of the U. S. Navy) had listened very carefully and would probably require hereafter a guarantee of consumption of fuel, along the line of similar guarantees as to speed and horse-power.

Then followed the reading of a portion of Mr. Charles Ward's paper on "Coil and Tubulous Boilers," which was accompanied by supplemental data from Mr. McFarland, from the standpoint of the experience of the United States Navy in adopting this type of boiler in the *Monterey*. There is no doubt that the Navy is highly pleased with its experience in this regard. In concluding his remarks Mr. McFarland said that the great question with the tubulous type of boiler is the life of the tubes, making the general statement that, in the case of the steel tubes ordinarily used in the cylindrical boilers of the Navy, this is but about three years. The following data were presented as the result of tests made by the Navy:

	Evap., f. & a., 212° per lb. of coal.	Evap. per sq. foot heating surface.	I.H.P. per ton of boiler and water.	Air pressure, inches of water.
Thornycroft	11.90	1.40	15.6	Open fire room
	9.72	3.63	40.44	0.5
	8.84	5.51	61.38	3.0
	6.51	6.70	74.65	4.0
Towne	5.82	5 32	33.90	2.0
Cowles	7.45	6.96	61.07	2.0
Ward	7.31	8.62	76.98	2 0
Cyl. D. F.	.....	.....	29.20	2.25
Cyl. S. E.	10.20	3.08	5.16	0.2
Locomotive	6.62	20.09	71.85	4.95

Mr. E. E. Roberts, of the Roberts Water Tube Boiler Company, followed with an extended and most interesting address that showed a wide knowledge of the subject, although, as he explained at the opening, his boiler has not figured largely in government tests, nor in the scientific discussion, as the company has been very busy supplying hundreds of boilers throughout the country, but which are not, of course, for large ships. The discussion was continued by Messrs. Dickie, Sweeney, Oldham and C. D. Mosher, the latter promising to send in data of tests of some of his boilers under air pressures as high as 12 inches of water, and with a combustion of over 200 pounds per square foot of grate.

Other papers considered briefly at Thursday's session, and which were left over from Wednesday, were the following: "Problems Confronting the Designer of Naval Machinery, and the success which has been Attained in their Solution," by I. N. Hollis, passed assistant engineer, U. S. N., assistant to engineer-in-chief; "The Strength of Ships," by F. L. Middendorf, technical director of the Germanischer Lloyds; "Practical Stability Information," by A. R. Liddell; "Diagram of Stability for any Draft and Stowage," by Pedro P. Seoane, commandant of engineers in the department of Ferrol, Spanish Navy.

THANKING FOREIGN VISITORS—THE PROCEEDINGS.

On Friday, the last day given to the divisions for separate discussion, the programme included some very important papers, as follows: "Speed Trials," by Archibald Denny, partner in Wm. Denny & Bro., Dumbarton; "Coasting Sailing Vessels of the Adriatic," by Rodolfo Poli, of the firm of Poli Bros., Chioggia, Italy; "Steel Castings for Marine Machinery," by Edwin S. Cramp, superintending engineer, Wm. Cramp & Sons; "Tests of Iron and Steel," by Jas. E. Howard, engineer of tests, Watertown arsenal; "Valves and Valve Gears for High Speed Engines," by N. P. Towne, chief engineer U. S. N., and consulting engineer to Wm. Cramp & Sons; "Western River Steamers," by J. M. Sweeney, of Harvey, Ill.; "Steam Shipping of the Great

Lakes," by Walter Miller, superintending engineer Globe Iron Works Company, Cleveland, Ohio; "Steamers of the Great Lakes Compared as Regards Strength," by J. R. Oldham. Unfortunately, two of the papers on the programme Friday were not in print, which prevented an extended discussion, and a third, that of Mr. Miller, of Cleveland, had not been furnished by the New York printers in time for study by the engineers. Such of the papers as were in readiness, however, were taken up and were discussed in a brief way during the few morning hours before the final adjournment.

Just previous to the close, the foreign visitors were accorded votes of thanks for their attendance, and they responded with liberal compliments to their friends in the United States. Commodore Melville and Passed Assistant Engineer McFarland were warmly congratulated on the success of the gathering, and thanked for their efforts of a year or more in preparing for the congress. There can be no doubt that the published volume of the proceedings, including the papers and the discussions, will be one of the most valuable collections of information in regard to marine engineering and naval architecture that has ever appeared. Arrangements have been made with Messrs. John Wiley & Sons, of No. 53 east Tenth street, New York City, for publishing these proceedings in book form, and subscriptions may be sent to these gentlemen. It is the desire of Commodore Melville to have these proceedings circulated as widely as possible, so that anyone who wishes to purchase them can do so by addressing the Messrs. Wiley, and remitting the price of subscription. The proceedings will comprise some 1,500 large octavo pages, including about 200 plates.

A general meeting of the divisions on Saturday, at which Vice-Chairman Chanute presided, closed the congress. Chairmen of the several divisions made reports upon the work accomplished, and then the engineers from abroad were called upon for remarks. They were astonished by the boldness of American engineers, who are solving most difficult problems. When representatives of all of the foreign nations had spoken the congress was declared closed. In the evening an informal reception was

tendered the visiting engineers at No. 10 Van Buren street, the headquarters of the associated engineers of Chicago.

Col. E. A. Stevens, of Hoboken, president of the New York and Hoboken Ferry Company, was among the most prominent young men at the Chicago meeting. He is a son of the late Edwin A. Stevens, of Castle Point, N. J., who was one of the most prominent early promoters of steam navigation in America. Col. Stevens is a graduate of Princeton College, of New Jersey, he having preferred a regular classical course in that institution to one of a more technical character in Stevens Institute of Technology, which was so liberally founded and endowed by the Stevens family. In the deliberations and discussions of the congress Colonel Stevens' remarks were invariably extremely interesting, and showed a remarkable amount of empirical information relating to the uses of steam in navigation that might be instructive to the closest student of science.

THE NEW DEFENDERS OF THE *AMERICA'S* CUP.

The following information is from the New York "Sun:"

We publish herewith the sheer plans and midship sections of all the cup defenders now being built, and also of the Carroll 84-footer *Navahoe*, which was recently launched. Yachtsmen will see at a glance the wide difference in types of the Herreshoff boats, and of the Boston boats as well. Taking the Herreshoff boats in their order, the *Navahoe* has the greatest over-all length of the three, being 128 feet from tip to tip. Her water-line length is 84 feet, and her draught 12.5 feet. She has a round stern, ending in a knife edge, and there is also a little sweep to her stem above the water. She is built of steel, her frames being $3 \times 2\frac{1}{2} \times \frac{1}{4}$ inches, spaced about 20 inches on centers, similar to those on the *Alcaea*. She has a plate centerboard $1\frac{3}{4}$ inches thick, which weighs about 3 tons. It is 17 feet long, and drops nearly 10 feet, so that the boat will draw with the board down about 22 feet. She is 23 feet beam, with slack bilge, and the keel measures in its widest part about 42 inches.

The second cup boat designed by the Bristol firm was for the Rogers syndicate. She is a keel, and measures 124 feet over all, or 4 feet less than the *Navahoe*. She is 24 feet beam, and has a draught of 14 feet. She is built of steel, her frames being similar to those on the *Navahoe*, spaced 21 inches on centers.

The Morgan syndicate boat is 26.3 feet beam, and has more draught than it was thought she would have, being not far from 13.5 feet. Her under body will be plated with Tobin bronze, the top sides of steel. This is the first time that Tobin bronze has been used on a yacht. The bottom is smoother, offers less resistance and creates less friction. The boat measures about the same as the Rogers boat over all, and both are close to 85 feet

on the water line. The line of the counter aft has a good sweep to it, thus making a curve line aft similar to that of the bow. The bottoms of the keels of both the Rogers and Morgan boats measure about 35 inches in their widest part. The overhang forward in the Morgan boat is greatest of the three Herreshoff yachts, while the overhang aft is the shortest. The keel of the *Navahoe* is the shortest, with the Rogers boat next, the Morgan boat the longest. The latter will be fitted with a Tobin bronze plate centerboard.

The two Bristol cup defenders will both have larger sail spread than the *Navahoe*, and the Morgan boat will have tremendous spars. The length of the keels runs from 45 to 54 feet. In the shape of their lateral planes of under-water bodies the yachts are very similar. Each has considerable drag. Look for almost a 100-foot main boom on the Morgan boat, because her dimensions plainly show that she will be very powerful. She is a centerboard, so that the Bristol firm will have two centerboards and one keel to represent them in the big single-sticker class. Some comments are being made on the fact that Designer Herreshoff has not turned out a purely fin boat in one of his three orders. Such questions are being frequently asked by most intelligent yachtsmen, both here and in New York. It is safe to say that had Herreshoff thought anyone else would come into the field with a fin boat, he would have gotten up one.

The John B. Paine boat will be a centerboard fin, with a small centerboard foreward to keep her from falling off in light winds. The boat is the most radical departure yet made in the fin type. she is close to 124 feet over all, about 84 feet load water line, and 22.5 feet beam. Her draught will be just under 14 feet, and with the board down, about 6 feet more. She is what might be called a "skimming-dish fin," as she has a light draught, and on a reach and run she should be very fast. She will be built of steel in Lawley's yard. She is a well-turned boat, with easy diagonals and rather full water lines forward. As in all fin boats, her section lines are easy. She is tons less displacement than any of the Herreshoff productions, and lacks the power of the Rogers and Morgan yachts.

The Boston syndicate boat is not very different from the Paine boat, so far as the boat herself goes. The beam is quite a foot more, and the over-all length is about 122 feet. The draught of the boat herself is not far from 4 feet, and the length of the load-water line is 85 feet. She has more dead rise to her midship section than the Paine fin, and an easier bilge. So far as the forms of the two go, the Stewart & Binney boat has the easier. She has good overhangs and easy ends. She will have a deep fin, with a lead bulb on the bottom, and when afloat she will draw 22 feet.

As to displacement, there is not much between the two fin boats. It will be a close thing between the pair, and handling will have considerable to do with the result.

Her designers have given the boat such a big draught because they wanted to get enough power to carry the sail they intend putting on, consequently they had to make the lever long, and she will not have to carry as much lead as she would if she were shoaler. Like the Paine boat, she will be built of steel. Pusey & Jones, of Wilmington, Del., are going to build the hull.

Her spar plan will be smaller than on any of the Bristol boats. Her displacement is not far from ninety tons, and this will leave somewhere about thirty tons for ballast. There is considerable logic in the statement that she will have to be hauled out but twice possibly for the trial races and the cup races. The following table gives very close approximate dimensions of the new American boats:

Name and Owner.	Length over all.		Length water line.		Extreme beam.		Draught.	
	ft.	*in.*	*ft.*	*in.*	*ft.*	*in.*	*ft.*	*in.*
R. P. Carroll's *Navahoe* (C. B.)	128	00	84	00	23	00	12	06
Rogers Syndicate (K)	124	00	85	00	24	00	14	00
Morgan Syndicate (C. B.)	124	00	85	00	26	03	13	06
Paine's fin boat	123	00	84	00	22	06	14	00
Boston Syndicate (fin)	122	00	85	00	23	10	22	00

C. B.—Center board. K.—Keel.

In many of the above cases the dimensions are exact. All the boats will be of steel construction except the Morgan boat, which, as has been stated, is to have a Tobin bronze bottom. There will be no wooden or composite built boats in the *America's* Cup fight this year except the British boat, the *Valkyrie*. So far as construction goes, the American boats will be on a more even footing than ever before, as no designer has much advantage over the other in material or weight. In tying the keel plates to the floors and frames, Herreshoff has adopted the same style as on the schooner *Alcaea*, which was built last season by Lawley. The keels raise about ten inches from a straight line forward.

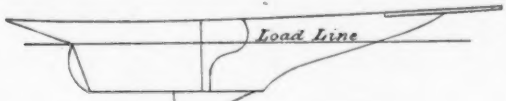
"Seaboard," in the issue for May 18, gives the following additional information about the *Pilgrim* (the Stewart & Binney fin boat):

The Pusey & Jones Co., of Wilmington, Del., have under construction a steel sloop which it is their hope, as it is that of her designers, Messrs. Stewart & Binney, of Boston, that she will be the "chosen one."

"Seaboard" is able to present herewith what we are informed is a correct outline of her hull and fin keel. The principal dimensions of the boat are as follows: Length over all, 120 feet; water line, 85 feet; beam, 23 feet; draught of hull, 5 feet; depth of fin, 17 feet—total draught, 22 feet. These dimensions give her an over-all length of a few feet less than the Herreshoff boats, the beam of the *Navahoe*, and six feet more draught than even the Rogers boat. She is the most radical departure yet made in American yacht designing, and if she is successful a new line for big racing yachts will have been marked out. Her great draught, the greatest ever put on a racing yacht, would alone stamp her as a remarkable production, but when many other things in the design are taken into consideration, it is not far out of the way to say that the performance of no single one of the cup-defense fleet will be watched with more interest by yachtsmen and yacht designers on both sides of the ocean.

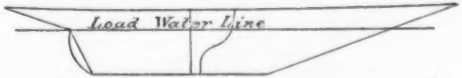
As to the rig which she will carry, it can be said that, while it will be larger than that of the old *Volunteer*, it will be the small-

est of the four cup defenders. The spars are now being made at Lawley's. The head rig will be a small one. Comparing the *Pilgrim* with the other big single-stickers, it will be found that she has the least displacement (less than 100 tons), the easiest form to drive and the best rig to handle. Those who are most interested in her and who know much about her see no reason why she should not be a fast and able craft.



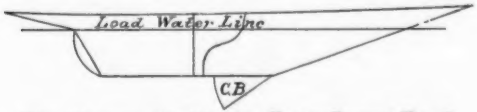
Royal Phelps Carroll's Navahoe.

The Paine Double Centreboard Boat.



The Rodgers Syndicate Keel Boat.

The Stewart & Binney Fin Boat.



The Morgan Syndicate Centreboard Boat.

THE NEW TORPEDO CRAFT OF THE BRITISH NAVY.

["Engineering."]

It is satisfactory to know that the British Navy is making an effort to take its proper leading position in the matter of speed of small craft. For many years the highest productions of our torpedo-boat builders were constructed to the order of foreign governments. The fact is not very creditable to the country in which the torpedo-boat originated, and which holds the premier position in the construction of these beautiful little craft. In the new type of torpedo-boat destroyer which has been ordered by the Admiralty, the speed of 27 knots has been stipulated for, carrying a load of 30 tons, and there is no doubt that this will be obtained.

In a recent visit to Messrs. Yarrow & Co.'s yard, we had an opportunity of seeing the vessels they have in progress, which are now well forward. There are on the stocks two twin-screw destroyers. These are plated up, and the machinery will shortly be ready to be put in. The three first-class torpedo-boats this firm is also constructing for the English Admiralty are likewise fully plated and ready to receive the machinery. The destroyers are known as the *Havoc* and the *Hornet*. Their length is 180 feet, and the beam 18 feet 6 inches; the rise of deck is about 8 inches. These vessels are practically large torpedo-boats, and appear to be on the model of the first-class boats built by this firm; they have long, easy bows, and the rising floor characteristic of the Poplar boats. The midship section of these boats is of the usual torpedo-boat type, with a fairly high floor, easy bilge, and tumble home on the top sides. Long experience has resulted in the selection of this form as combining speed

and seaworthiness in a high degree. The latter quality is enforced by the hood forward. This hood, or turtle back, forward is, however, somewhat differently arranged, and is, we think, an improvement on the torpedo-boat design, as it affords superior sea-going qualities. In the torpedo-boat, the turtle back only extends from side to side of the boat, until it gets as far aft as nearly to the position of the conning tower. Here it is swept in on each side to join the conning tower, leaving two flat pieces on deck on each side of the latter. This arrangement is very clearly shown in our illustration of a torpedo-boat built for the Victorian Government by Messrs. Yarrow, as shown in our issue of January 22, 1892 (vol. liii, page 105). In the destroyers, however, the turtle back is carried right aft to the after part of the conning tower. In this way additional protection is given to the decking just abaft the conning tower, and this protection is increased by high bulwarks on each side at that position. The shielding against water coming on board is further provided for by a couple of deck houses placed here, and advantage has been taken of the position to mount two 6-pounder quick-firing guns. These guns could be worked in bad weather, so far as protection against the elements is concerned, and the men are almost concealed from forward when working the guns.

Another novel feature in this vessel—that is, novel as compared to torpedo-boat practice—is the working in forward of a water-tight flat, at or about the level of the water line. This is carried aft to the forward boiler-room bulkhead, so that practically a double bottom is obtained for this part. It is divided up by cellular construction into various receptacles for ammunition, stores, &c. In this way the features which have been always insisted upon by the present director of naval construction, Dr. White, of double bottom and subdivision, are carried out, and doubtless the necessity for these provisions was emphasized by the accident to the *Apollo*, and her fortunate escape in spite of the rough usage she received. These destroyers are essentially sea-keeping vessels, and would have to go to sea and stop there as long as required. In connection with this feature, it may be said that the boat outfit is more complete than in torpedo craft,

there being in each vessel a 24-foot whaleboat carried in davits (the latter being apparently of a novel form), and two 20-feet Berthon boats, in addition to a dinghey. The formation of the stern of these vessels is similar to that which has been adopted for torpedo boats by this firm. The dead wood is cut away aft, the rise from the keel beginning from about 45 feet to 50 feet from the stern post, and running up to just about the water line, right aft. The stern is somewhat rounded, there being no counter; but as it is carried only to the surface, bluff lines do not matter, although the appearance of the vessel on the stocks is not suggestive of speed. The sternpost is inside the plating, and consists of a steel forging which projects above the deck a few inches, and below the hull through the plating. In this way pintles are formed for carrying the rudder. This sternpost is flattened on the part below the deck and that above the bottom plating, so that the portion inside the vessel is treated in this way, and forms, as it were, a butt strap for the attachment of the plating. The method of construction is very strong and rigid. The rudder itself deserves attention. It is of the form which is usual in first-class boats built by this firm. It is hung in a novel manner upon the sternpost already referred to. The bottom pintle acts as a guide, the weight being taken by the top one. In the event of the rudder being damaged, it is only necessary to remove one nut and the whole can be dropped, a point which might prove of very great convenience in war time, as no rudder at all is infinitely preferable to one bent or deflected. The rudder itself is of the partially balanced type, a large part extending below the bottom, and the surface is so distributed that on the helm being put hard over the water does not escape over the top, full advantage of the stream lines being thus secured. The area also is distributed in such a way that, when the vessel is turning, the pressure of the water on the rudder tends to counteract the heel of the boat, and this, of course, adds to the stability at a critical period. This feature we have alluded to on a former occasion, when describing the trials of this firm's torpedo boats. The propeller-shaft brackets or A-frames must necessarily be a novel shape in a vessel with no deadwood. They were not in

position at the time of our visit, and were being machined in the shops. A double-angle iron is on the bottom of the vessel aft, and is evidently intended for the attachment of the shaft brackets. The propellers are three-bladed, and were in course of construction at the time of our visit. They have forged-steel blades, keyed into steel bosses of the ordinary torpedo-boat type as used by this firm.

According to the published accounts, these vessels are to carry three quick-firing guns. One of these is, we believe, to be a 12-pounder Hotchkiss, and will be placed on the top of the conning tower. The other two guns are, as stated, just abaft the turtleback forward, but there is provision made in the deck for alternative positions further aft, supposing the alteration be considered necessary. The usual searchlight will be fitted.

There are three torpedo discharges, consisting of a double-torpedo gun on a turntable aft, and a tube built into the hull forward, the latter of course, discharging right ahead and necessitating the manœuvring of the vessel in order to train it on an object. There is to be a transporting carriage for torpedoes, running on a railway, which goes from the conning tower forward to the turntable on which the torpedo guns are placed aft. According to present plans there will be only one mast forward, and this is not to carry sail, acting simply as a boom derrick for the handling of boats and torpedoes and for signal purposes. An important detail, which has been very carefully considered in the design of these craft, is the ventilating arrangements—a matter too often little considered in similar vessels. The boat's complement will be about 40, the crew being berthed forward, and the officers and petty officers aft. In a boat under 200 feet, to run at 27 knots, there is not much room left after the machinery has been provided for, but in these vessels there will be a good deal more accommodation than in the ordinary first-class torpedo boat, even relatively to their size. Messrs. Yarrow have managed to compress the machinery to within 76 feet of the length of the boat, according to measurements between bulkheads. The fitting of the cabins is to be more complete than is usual in vessels of the kind, owing

to the sea-keeping duties for which they are designed. The wardroom and cabins aft occupy the space of about 30 feet, and quarters are to be very completely fitted up in the fore part. More attention than is usual has been given to the comfort of the men, a special point having been made in this respect with regard to ventilation, sleeping accommodation and locker space.

There are thirteen 'thwartship bulkheads, and there are also other divisions, forming about twenty water-tight compartments in all. They are, of course, all connected to the bilge ejection. In the machinery space the bunkers afford coal protection to the boilers, and add to the longitudinal strength in this part of the hull. The conning tower is formed of ½-inch steel plate, and is, therefore, from a torpedo-boat point of view, an armored structure.

The machinery is not the same in both vessels, there being the important difference of water-tube boilers in one case and locomotive boilers in the other. In all other respects the vessels are similar. The fact will naturally make the *Havoc* and the *Hornet* two of the most interesting craft in the Navy. If Mr. Yarrow can beat his own locomotive boilers there is nothing more to be said for the type, and here will be a fair chance of settling the matter.

The *Havoc* is to have two locomotive boilers of the type adopted by Messrs. Yarrow, with which our readers are familiar. They will each, we believe, be more powerful than any hitherto constructed. The fire-boxes and tubes will be of copper. The *Hornet* will be provided with eight water-tube boilers of the Yarrow type. The object in having such a large number was—firstly, in the event of one boiler being disabled, not to diminish materially the power developed; secondly, to facilitate the removal of the boilers, in the event of heavy repairs being necessary, in which case it is desirable to avoid lifting any large weight, such as would be involved if the boilers were not so much subdivided. One important departure in these boilers is the adoption of copper instead of steel tubes, thereby avoiding pitting action, which experience has proved to be so rapid when the latter material is used in water-tube boilers. The Yarrow

type of boiler admits of the adoption of copper, owing to the fact that the tubes are always filled with water, having all portions below the water level.

The engines for both boats are fairly advanced, those for one vessel being ready to put in. They consist of triple-expansion three-crank engines, of the usual type adopted by the firm, being specially designed for fast running; the cylinders are 18 inches, 26 inches and 39½ inches; working pressure, 180 pounds. There are piston valves throughout. Whether any provision is to be made for balancing, on Mr. Yarrow's system, is not apparent in the present state of the work, but it is to be hoped that such an opportunity as this will not be lost, of testing the system on a large scale. The necessity for reducing the vibrations in passenger ships is becoming more pressing every day, and is especially instanced by a most important vessel, which has recently been tried.

The three torpedo-boats are each 140 feet by 14 feet 6 inches. They are single-screw, and have in two of the boats triple expansion engines and locomotive boilers, the steam pressure being 180 pounds. In the third boat a quadruple-expansion engine will be placed. In this vessel there will also be two water-tube boilers of an entirely new type, about which we shall have something to say at a later date. The working pressure in this case will be 220 pounds.

THE NEW CLASSIFICATION SOCIETY.

["Engineering, May 19, 1893."]

Since the absorption of the Liverpool organization for the registry of shipping by Lloyd's, the latter has had an unchecked advance towards a position which, however satisfactory to the management, is not quite agreeable to the client. The spirit of the age is entirely opposed to monopoly, which, in great measure, retards progress. The all-powerful position of Lloyd's has fostered a conservatism which is adverse to the adoption of new ideas, even when suggested by ripe experience. Innovations are not always to be commended, and Lloyd's have very properly observed caution in some respects; but in other instances, where the change has been forced on the marine constructor by the satisfactory character of preliminary tests, the contravention of the letter of Lloyd's Rules should scarcely have been sufficient to bar progress. Thus it is that many have at various times been annoyed, and the spirit of opposition has been fostered. The culminating point was reached when the Load Line Act of 1890 was passed, because shipowners foresaw that without action Lloyd's would have, under the enactment, a sole right in the determination of what was to constitute the load line. The load line depends upon scantlings, and this meant that Lloyd's would have a monopoly of classification also. This would, under the circumstances, have been most unfortunate, as it would have tended to check enterprize in shipbuilding, and reduce marine constructors to the level of manufacturers. The British Corporation for the Survey and Registry of Shipping was therefore formed, not so much in antagonism to Lloyd's, but because of the profound conviction that monopoly is not de-

sirable. Its great strength is largely due to the fact that it comprises shipbuilders, marine engineers, &c., as well as shipowners and representatives of all classes of shippers. Not only is it representative in this respect, but it comprises within its organization nearly all the Clyde men of influence, and many of those in the North of England, Ireland, and Liverpool. We have at various times indicated the successive steps in the organization, and now that its position is assured, it is interesting to consider the regulations on which the survey and registry are based, and which were issued in book form at the annual meeting on Friday last.

These rules are primarily the work of the late Professor Jenkins and Mr. Archibald Denny, of the well-known Dumbarton firm, and their explicit and concise definitions are most commendable. The idea with which they set out, indeed, was that the rules of existing registries are more or less difficult of application and uncertain in their results, that a small increase or decrease in any of the three principal dimensions of a steamer may mean a large increase or decrease to the weight of the hull quite out of proportion to the change in size, and that this is caused by gradings which necessitate sudden jumps from one set of scantlings to another. These objectionable features have been guarded against. In the first place, there is but one class—the B.S., signifying compliance with the British Standard, a happy designation; and the only distinguishing mark for strength will be the load line assigned to the vessels. This is but the logical sequence to the Freeboard Tables.

In the important matter of scantlings, the thickness of all material is specified in 40ths for steel, and these are to be read as 32ds for iron. This will be an advantage in the gradual increase of scantlings with dimensions. The present 20th was regarded by the framers of the rules as too great a jump. The actual moulded dimensions are taken, and not hypothetical measures varying with the style of vessel. One special feature of the rules, of interest in this age of specially large and exceptionally powerful steamers, is that these are not to be subjected to any closely-drawn limitations. The rules are to apply to vessels the moulded

length of which does not exceed fourteen times the depth, which, again, is not to be less than 55 per cent. of the beam. Vessels beyond these proportions are to be specially considered, and these latter will probably include only the special types we have referred to.

The details of scantlings are arranged in tabular form. For keels, stems, etc., the dimensions used are length and depth. The practice of other registries is to determine that the larger the ship the heavier should be the keel; but Mr. Denny and the members of his technical committee seem to have gone on the idea, now generally accepted, that while this is right so far as stem and sternpost are concerned, it is enough that the keel, which is now regarded as of secondary importance in the matter of strength, is sufficiently deep and thick for the riveting of the garboard strake. The speed of a steamer is also accepted as a factor in determining the strength of the propeller frame and the diameter of the rudder stock; this provision, while made in the case of the Bureau Veritas, is not in Lloyd's regulations. As in other registries, the frames and flooring are according to the breadth and depth; while as to the disposition, etc., of frames, a series of sketches indicate clearly the expectations of the "British Standard." In determining the sizes of shell-plating, keelsons, etc., only the length of the vessel is considered; this is a departure from the methods of other rules, but the regulation sizes seem to agree with ordinary practice. The British Standard frame spacing rises pretty uniformly with the length of the steamer, whereas with Lloyd's the 24-inch spacing is applicable to most of the ships built. The scantlings of deck stringers, plates, tie-plates and deck-plating are most carefully specified, while in the plating of erections on deck the thicknesses are far in excess of Lloyd's—a 500 feet long vessel requiring $\frac{7}{10}$-inch plates—but this is very essential in a part of the structure most liable to "working." The bulkheads are arranged pretty much on the same principle as in the Board of Trade Bulkhead Committee's Report, but sailing ships having after pumps will require to have after-peak bulkheads, in addition to those specified in the Bulkhead Committee's Report. As

to the riveting of the whole structure, it is noteworthy that steel rivets have a premium put upon them.

There is an interesting practice of the designer, known as "the skinning of scantlings"—quite a profitable one, too. The jumps in the series of scantlings, to which reference has been made, have in many cases induced the shipbuilder and shipowner to reduce one dimension, sometimes by an inappreciable size, and thus avoid an increase in scantlings. The British Corporation rule gets over the difficulty by intermediate scantlings for intermediate sizes, so that there is no incentive to depart from the dimensions which will secure the best results in respect of stability and speed. For intermediate sizes the scantlings, it is indicated, may be obtained by interpolation.

The formulæ given in the machinery rules are a close approximation to the latest Board of Trade rules, although, as in the case of most other regulations in the book, they are more explicitly specified. The only distinct departure which is worth mentioning is that the Fox, Purvis, Morison, and Adamson ring flues are all classed under one common factor.

There can be no question of the great care with which the rules have been prepared. They indicate clearly that the Technical Committee has a full grasp of modern practice, and, it almost goes without saying, a sympathetic interest with those having grievances against the conservative, if not occasionally autocratic, tendencies of Lloyd's. All the elements of success are present. Those associated with the undertaking are men of influence. The staff of surveyors has for chief Mr. W. T. Courtier Dutton, formerly of Lloyd's surveying staff, and already a good start has been made, for the Registry, as was reported at the annual meeting, have assigned load lines to upwards of 600 ships, aggregating nearly a million tons, while several vessels have been built and ten are under construction, in addition to a dozen sets of engines, in accordance with the rules which we have summarized. The registry book contains the classification of upwards of 500 vessels, and the comprehensive information regarding the vessels should be most serviceable.

AMSLER'S POLAR PLANIMETER.*

By C. W. Crockett.

[Reprinted from the "Polytechnic."]

I. DESCRIPTION.

Amsler's Polar Planimeter consists essentially of a bar NF, pivoted at F to the frame E carrying a wheel W with a horizontal axis. A second bar AC, that fits in and may be made to slide

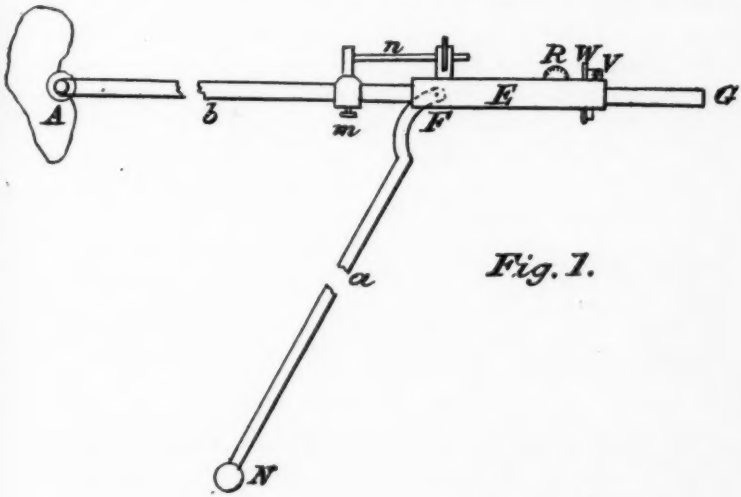


Fig. 1.

along the sleeve E, is graduated and provided with a clamp and slow motion screw (m and n) so that a pointer at A may be set at different distances from F. The pointer A, the pivot F, and

*Prepared for the class of 1892 of the Renssalaer Polytechnic Institute.

the axis of the wheel should be in the same vertical plane, and the instrument is constructed so that W cannot pass between N and F. When in use the planimeter rests on the paper at three points—one on the circumference of the wheel and the others at N and A, the point N being fixed. When the pointer A is made to follow an irregular curve drawn on the paper, the wheel will be made to rotate by its friction on the paper, having both a sliding and a rotary motion. To measure the amount of rotation the circumference of the wheel is divided into 100 equal parts, and by the vernier V it is read to thousandths of a turn, the roller R showing the number of complete turns up to ten.

II. THE ZERO CIRCLE.

If the pointer be made to follow a circle with its center at N, the triangle ANF will not be changed, and therefore any point on NF or AW will describe a circle with its center at N. When the pointer moves on the circle such that the plane of the wheel passes through N, the wheel will describe a circle whose tangent will take the direction AW, so that the motion of the wheel will be in a direction perpendicular to its plane and it will not rotate. This circle, described by the pointer without rotation of the wheel, is called the *zero circle*, and its radius is

$$r_0 = \sqrt{a^2 + b^2 + 2bc} \qquad (1)$$

where $a = NF$, $b = AF$, and $c =$ projection of a on $b = FW =$ the distance from F to the plane of the rim of the wheel. The distance $AF = b$ may be changed while a and c are constants; hence the radius of the zero circle will vary with b.

III. DIRECTION OF ROTATION.

In figures 3 and 4 let the angle $ANB = d\theta$, AB and CD being circular arcs with their centers at N, and let $NG = r_0 =$ radius of the zero circle.

When AB is *outside* of the zero circle (Fig. 3) the pointer moving over the infinitesimal arc AB from A to B (or clockwise) will cause the wheel to move from W to W^1. This motion may be resolved into WE, perpendicular to the plane of the wheel and not causing it to rotate, and EW^1, parallel to the plane of the

wheel and causing rotation. Moving the wheel over EW^1 will cause it to rotate clockwise (looking in the direction WA) and will cause the reading of the wheel to increase. If the pointer were moved over BA from B to A (or counter clockwise) the wheel would rotate by the same amount, but in the opposite direction.

When AB is *within* the zero circle (Fig. 4) the motion over AB will cause the wheel to move from W to W^1, resolvable into WE and EW^1. The motion of the wheel over EW^1 will cause it to rotate counter clockwise (looking in the direction WA). When the pointer is moved from B to A the wheel will rotate clockwise.

Hence, when the pointer is moved clockwise over a circular arc with its center at N,—

arc outside of the zero circle, rotation is clockwise;
arc within the zero circle, rotation is counter clockwise.

When the pointer is moved counter clockwise the direction of the rotation of the wheel is reversed.

We shall call *clockwise rotation positive* since it increases the reading of the wheel, and hence counter clockwise rotation will be negative.

IV. CONNECTION BETWEEN ROTATION AND AREA.

Since any area may be considered as being composed of an infinite number of infinitesimal elements similar to $ABCD$, the polar element of area in Figs. 3 and 4, we shall consider the effect upon the wheel of moving the pointer over the perimeter $ABCD$—over the two radial lines BC and DA and over the arcs AB and CD.

1. If the pointer be moved over BC the wheel will rotate by a certain amount, and if the pointer be now brought back over CB to B it will rotate by an equal amount in the contrary direction, thus bringing the wheel into its first position. Also if the pointer be moved from B to C and if the wheel be then lifted from the paper to prevent rotation while the pointer is moved to D, the angle between the arms a and b of the planimeter will be the same when the pointer is at D as it was when the pointer was at

C. Hence moving the pointer over *DA* will have the same effect on the wheel as the motion over *CB*. Therefore the rotation of the wheel produced by moving the pointer over *BC* will be neutralized by that produced when the pointer is moved over *DA*. *In considering the rotation of the wheel, caused by moving the pointer around the figure ABCD, we may neglect the radial lines and consider only the circular arcs.* Hence *AD* and *BC* are not necessarily infinitesimal, so that we may treat any plane area as being made up of an infinite number of infinitesimal parts, each bounded by radial lines from *N* inclosing an angle $d\theta$ and by arcs with their centers at *N*, as *gh pq* in Fig. 2.

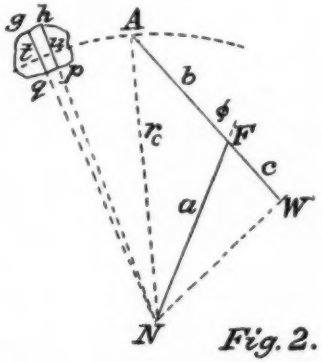


Fig. 2.

2. The arc *AB* may be *outside* of the zero circle or *within* it. Suppose the motion of the pointer over *AB* to be clockwise, and let the distance $NA = r$.

(*a*.) *The arc outside the zero circle* (Fig. 3).

When the pointer is moved over the infinitesimal arc *AB* the wheel will describe a circular arc with its center at *N* and with the radius *NW*;

$$\therefore \text{ arc } WW^1 = NW\,d\theta.$$

The portion of this movement of the wheel that causes rotation is

$$\begin{aligned} EW^1 &= WW^1 \sin W^1WE \\ &= WW^1 \sin (\alpha - 90^\circ) \\ &= -WW^1 \cos \alpha \\ &= -NW \cos \alpha \, d\theta \end{aligned}$$

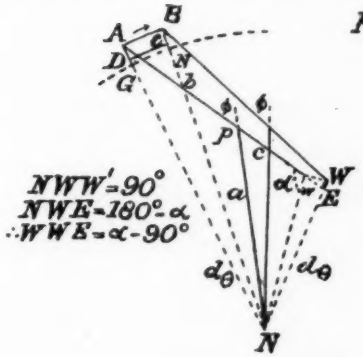


Fig. 3.

From the triangles NAW and NFW we have

$$r^2 = (b + c)^2 + NW^2 - 2(b + c) NW \cos \alpha$$

and

$$a^2 = c^2 + NW^2 - 2c \, NW \cos \alpha.$$

Subtracting and reducing, we have

$$\begin{aligned} NW \cos \alpha &= \frac{1}{2b} (a^2 + b^2 + 2bc - r^2) \\ &= \frac{1}{2b} (r_0^2 - r^2) \end{aligned}$$

$$\therefore EW' = \pm \frac{1}{2b} (r^2 - r_0^2) \, d\theta, \qquad (2)$$

where $r > r_0$.

(*b.*) *The arc within the zero circle* (Fig. 4). The angle $W'WE$ is here equal to $90^\circ - \alpha$.

$$\begin{aligned} \therefore EW' &= WW' \sin (90^\circ - \alpha, \\ &= WW' \cos \alpha = NW \cos \alpha \, d\theta; \end{aligned}$$

and this by the method above gives

$$EW' = + \frac{1}{2b} (r_0^2 - r^2)\, d\theta, \tag{3}$$

where $r < r_0$.

These values of EW' give the *amount* of rotation. Considering the direction of rotation (III) we have for the rotation of the wheel when the arc is either outside of or within the zero circle,—

pointer moved clock-wise.

$$\textit{rotation} = + \frac{1}{2b} (r^2 - r_0^2)\, d\theta \tag{4}$$

pointer moved counter clock-wise.

$$\textit{rotation} = - \frac{1}{2b} (r^2 - r_0^2)\, d\theta \tag{4'}$$

where the relative values of r and r_0 will determine the *direction* of rotation.

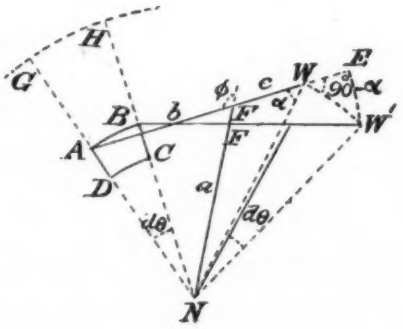


Figure 4.

In Figs. 3 and 4,

$$\text{area } ABHG = \tfrac{1}{2} (r^2 \sim r_0^2)\, d\theta;$$

hence the area between the arc AB and the zero circle is equal to the product of b by the *amount* of rotation caused when the pointer is moved over the arc AB.

The rotation produced by moving the pointer over the periphery of any figure will be the sum of the rotations produced by

moving the pointer around the infinite number of its infinitesimal portions (*ghpq*, Fig. 2). For in moving the pointer around the figure *abcdhgfe* (Fig. 5), if we represent the rota-

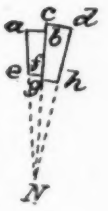


Figure 5.

tion due to *ab* by $\overline{ab}$, the total rotation will be

$$\overline{ab} + \overline{bc} + \overline{cd} + \overline{dh} + \overline{hg} + \overline{gf} + \overline{fe} + \overline{ea} = (\overline{ab} + \overline{bf} + \overline{fe} + \overline{ea}) + (\overline{bc} + \overline{cd} + \overline{dh} + \overline{hg} + \overline{gf} + \overline{fb})$$

since $\overline{bf}$ will be neutralized by $\overline{fb}$.

$$\therefore \text{Total rotation} = \overline{abfea} + \overline{bcdhgfb}$$
$$= \overline{ab} + \overline{cd} + \overline{hg} + \overline{fe},$$

the same as if the pointer were moved only over the circular arcs.

V. AREA OF ANY CURVE.

In using the instrument the needle-point N may be placed either outside of the area to be measured or within it, and there are three cases in each position:

(1.) Periphery entirely outside of the zero circle.

(2.) Periphery entirely within the zero circle.

(3.) Periphery partly outside of and partly within the zero circle.

(*A*.) Needle-point outside of the area.

(1.) The periphery entirely outside of the zero circle (Fig. 3).

Rotation corresponding to

$$AB = + (NA^2 - r_0^2) \frac{d\theta}{2b}.$$

Rotation corresponding to

$$CD = -(ND^2 - r_0^2)\frac{d\theta}{2b}.$$

$\therefore$ Resultant rotation

$$= (NA^2 - ND^2)\frac{d\theta}{2b}.$$

But area $ABCD$

$$= (NA^2 - ND^2)\frac{d\theta}{2}.$$

$\therefore$ area $= b \times$ rotation. (5)

2. The periphery entirely within the zero circle (Fig. 4).

Rotation corresponding to

$$AB = +(NA^2 - r_0^2)\frac{d\theta}{2b}.$$

Rotation corresponding to

$$CD = -(ND^2 - r_0^2)\frac{d\theta}{2b}.$$

$\therefore$ Resultant rotation

$$= (NA^2 - ND^2)\frac{d\theta}{2b}.$$

$\therefore$ area $= b \times$ rotation. (5)

3. The periphery partly outside of and partly within the zero circle (Fig. 6).

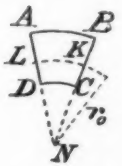


Figure 6.

Rotation corresponding to

$$AB = +(NA^2 - r_0^2)\frac{d\theta}{2b}.$$

Rotation corresponding to

$$CD = -(ND^2 - r_0^2)\frac{d\theta}{2b}.$$

$\therefore$ Resultant rotation

$$= (NA^2 - ND^2)\frac{d\theta}{2b}.$$

$$\therefore \text{ area} = b \times \text{rotation}. \qquad (5)$$

Therefore when the needle-point is outside of the area we have

$$\text{area} = b \times \text{rotation}.$$

If the circumference of the wheel be denoted by s and the number of turns by n, we have

$$\text{rotation} = sn$$

and $$\text{area} = bsn, \qquad (6)$$

where n is always positive if the pointer is moved clock-wise around the figure.

(*B.*) Needle-point within the area.

(1.) The periphery entirely outside of the zero circle (Fig. 7).

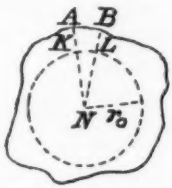


Figure 7.

Rotation corresponding to

$$AB = +(NA^2 - r_0^2)\frac{d\theta}{2b}.$$

Rotation corresponding to

$$LK = 0.$$

$\therefore$ Resultant rotation

$$= (NA^2 - r_0^2)\frac{d\theta}{2b}.$$

But area $ABLK$

$$= (NA^2 - r_0^2)\frac{d\theta}{2}.$$

$$\therefore \text{ area } ABLK = b \times \text{rotation}.$$

Hence the area between the curve and the zero circle $= b \times$ rotation, and to get the total area we must add πr_0^2, the area of the zero circle.

$$\therefore \text{ area} = \pi r_0^2 + bsn, \tag{7}$$

where n will be positive for clock-wise motion of the pointer.

2. The periphery entirely within the zero circle (Fig. 8).

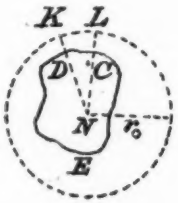


Figure 8.

Moving the pointer clock-wise around DCE (or counter-clock-wise around $DCLK$) we have:

Rotation corresponding to

$$DC = + (ND^2 - r_0^2) \frac{d\theta}{2b}.$$

Rotation corresponding to

$$LK = 0,$$

$\therefore$ Resultant rotation

$$= (ND^2 - r_0^2) \frac{d\theta}{2b},$$

and this will be a negative quantity since $ND < r_0$.

$$\text{Area } DCLK = (r_0^2 - ND^2) \frac{d\theta}{2}$$

$$= - b \times \text{rotation.}$$

But the rotation $= sn$, when n is a negative quantity, the reading of the wheel having decreased.

$$\therefore \text{ area } DCLK = - bsn.$$

Hence the area between the curve and the zero circle $= - b \times$

rotation $= -bsn$, and to get the area DCE we must subtract the area between the curve and the zero circle from the area of the zero circle.

$$\therefore \text{ area } DCE = \pi r_0^2 - (-bsn) = \pi r_0^2 + bsn, \qquad (7)$$

where n will be negative for clock-wise motion of the pointer.

3. The periphery partly outside of and partly within the zero circle (Fig. 9).

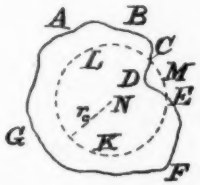


Figure 9.

Moving the pointer from E to C along $EFGABC$ will give a positive rotation equal to

$$\text{area } EFGABCLK \div b.$$

Moving the pointer from C to E along CDE will give a negative rotation equal to

$$\text{area } CDEM \div b.$$

The resulting rotation will be positive or negative according as the area $EFGABCLK$ or the area $CDEM$ is the greater; and the area of the curve will be, for clock-wise motion of the pointer,

$$\text{area} = \pi r_0^2 + bsn, \qquad (7)$$

where n is positive or negative according as the reading of the wheel has increased or decreased.

(*C.*) Summary.

Hence we have for clock-wise motion of the pointer around the figure:

1. Needle-point outside of the area,

$$\text{area} = bsn, \qquad (8)$$

where n is always positive.

2. Needle-point within the area,

$$\text{area} = \pi r_0^2 + bsn, \tag{9}$$

where n is positive or negative according as the reading of the wheel has increased or decreased.

VI. VALUE OF b.

The following dimensions of a planimeter were furnished by the makers:

$$s = 2.370 \text{ in.}; \quad a = 6.214 \text{ in.}; \quad c = 1.343 \text{ in.}$$

In this instrument the zero of the divided arm FA is found at A and the index mark on the frame that carries the wheel is opposite to F, so that the setting of the arm is the value of b.

1. To find b so that the *area of the diagram* may be found to hundredths of a square inch.

Then 0.01 sq. in. will correspond to one unit on the wheel-vernier ($n = 0.001$). Since $A = bsn$ (Eq. 8), we have

$$0.01 = b \times 2.370 \times 0.001.$$
$$\therefore b = 4.219 \text{ in.}$$

Therefore if the bar FA is set at 4.219 in., and if the pointer is then made to pass over the periphery of an area, the rotation of the wheel will give the area in hundredths of a square inch, each vernier-unit representing 0.01 sq. in.

2. Suppose that the *diagram* represents a *figure* on a scale of 1 : 96, and that we wish to find the area of the *figure* in square feet. By setting the arm at 4.219 ins., as before, we could find the area of the *diagram* in square inches, and then compute the area of the figure. We may, however, proceed as follows:

1 sq. ft. of the actual area corresponds to $1 \div 96^2$ sq. ft. of the diagram or to $144 \div 96^2$ sq. in. Therefore, since we wish each vernier-unit to correspond to 1 sq. ft. of the *figure*, $144 \div 96^2$ sq. in. of the *diagram* must correspond to one vernier-unit.

$$\therefore 144 \div 96^2 = b \times 2.370 \times 0.001.$$
$$\therefore b = 6.593 \text{ in.}$$

In using the instrument a mark is made on the periphery, the pointer is placed there, and the reading of the wheel is found. The pointer is then moved around the periphery until it returns to the starting point, when a second reading of the wheel is made. Suppose that the first reading was 2.403 turns and the second 5.677, the rotation would then be 3.274 turns, or 3,274 vernier-units. The area of the figure would be 3,274 × 144 sq. in., or 3,274 sq. ft.

3. Let the scale $= d$, and suppose that we wish each vernier-unit to correspond to y sq. in. of the actual figure. Then y sq. in. of the figure will correspond to yd^2 sq. in. of the diagram.

$$\therefore yd^2 = bs \times 0.001 ;$$

$$\therefore b = \frac{1000}{s} yd^2. \qquad (10)$$

Having found the value of n with this setting, multiply the number of vernier-units by y to get the area of the figure, since 0.001 of a turn corresponds to y sq. in.

Making $y = 0.01$ and $d = 1 : 1$, we have $b = 4.219$ as before.

Making $y = 144$ and $d = 1 : 96$, we have $b = 6.593$ as before.

From Eq. (10), since $1000 \div s$ is a constant, we see that b will be the same as long as yd^2 is the same. Hence the same setting may be used for different scales by assigning proper values to y. Thus, if $d = 1 : 96$ and $y = 144$, we have found $b = 6.593$. Here

$$yd^2 = \frac{144}{96^2} = \frac{1}{64}; \text{ or } d = \frac{1}{8\sqrt{y}},$$

and $b = 6.593$ would be the setting for scales found by assigning values to y,—

$y =$ 1 sq. in., $d = 1 : 8$
$y =$ 4 " ", $d = 1 : 16$
$y =$ 9 " ", $d = 1 : 24$
. . . . . , ...
$y = 144$ " ", $d = 1 : 96$

and so on.

4. Application to steam engine indicator diagrams, where the mean pressure is the quantity sought. Suppose the length of

the diagram is 4.17 inches and that the vertical scale is 40 pounds to 1 inch.

$$\therefore MP = \frac{40 \times \text{area}}{4.17}.$$

If we wish to find the mean pressure to tenths of a pound, each vernier-unit will correspond to 0.1 pound. The area of the diagram corresponding to a mean pressure of 0.1 lb. will be

$$\frac{1}{10} = \frac{40 \times \text{area}}{4.17}, \text{ or area} = 0.010425 \text{ sq. in.},$$

and we wish each vernier-unit to correspond to this area.

$$\therefore 0.010425 = b \times 2.370 \times 0.001.$$
$$\therefore b = 4.399.$$

If the values of s, a and c are not given, the following method may be used when a trial disk or a circle with a known area is provided:

Let A = area of circle, d = scale, and y = area of the figure represented by one vernier-unit, the areas being in square inches. The actual area of the figure represented by the circle is $A \div d^2$, and hence the number of vernier-units that would correspond to it is $A \div d^2 y$.

Thus if the scale is 1:300 and y is 10 sq. ft. = 1,440 sq. in., the number of vernier-units corresponding to the circle should be

$$A \div \frac{1440}{90000} = A \div 0.016.$$

By trial we would then find the setting so that when the pointer is moved around the circle the wheel will rotate through this number of vernier-units.

VII. HINTS.

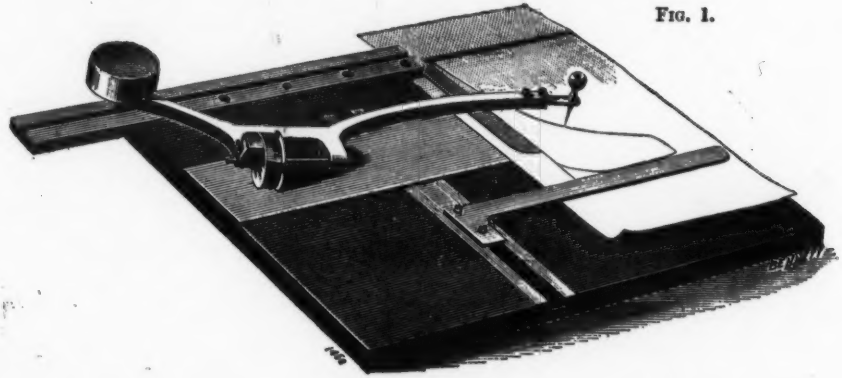
The mark at which the pointer is first placed should be so taken that moving the pointer for a short distance along the curve shall cause little or no rotation of the wheel; for in this way the error due to the non-return of the pointer to its exact starting point is reduced to a minimum.

In following straight lines use a ruler.

XU

THE COFFIN "AVERAGER."

FIG. 1.



Move the pointer slowly—not so fast but that the figures on the wheel may be read—to avoid effect of inertia.

It is better to place the needle-point outside of the area, as any uncertainty in the area of the zero circle is thus avoided. If the area is too large, divide it up by straight lines and find the area of the portions separately.

If the drawing is to a scale, when the needle-point is within the area, the area of the zero circle must be divided by d^2 in finding the area of the figure represented, the number of vernier-units of rotatian being multiplied by y.

Test the planimeter by going around the trial disk in both directions and with the trial disk at different distances from the needle-point. When possible also use different circles for testing.

COFFIN'S AVERAGING INSTRUMENT.

The following explanation of the theory of this special form of the Amsler Planimeter, reprinted from "Engineering," will be of interest to American readers, although they have been familiar with the instrument itself for a number of years.

The illustration opposite shows a very ingenious little integrating instrument, now being introduced by the Globe Engineering Company, Limited, of 38 Victoria buildings, Manchester, and specially intended for working out indicator diagrams. As our illustration shows, the instrument consists of an arm having at one end a tracing point, and at the other end a hardened spindle running in a brass groove as shown. The arm carries a graduated wheel, which runs on a prepared paper surface, the conditions being much more favorable than with an ordinary planimeter, where the registering wheel runs on common drawing paper. The axis of rotation of this wheel is, of course, parallel to the line joining the tracing point and spindle in the groove. To use the instrument, the diagram is placed in two clips, one of which—viz: that shown to the right in the figure—is movable, whilst that on the left is fixed, its edge coinciding in direction with the

center of the groove, in which one end of the arm of the instrument runs. To fix the diagram in place the tracing point is placed against the fixed clip and the diagram moved (keeping its atmospheric line horizontal) till its extreme left point is under the tracer. The tracing point is now moved to the extreme point of the diagram on the right, and the movable clip brought up against it. The distance between the clips is now, of course, equal the length of the diagram. By pressing, a slight indentation is made on the paper with the tracing point, and the roller having been set to the zero mark, the pointer is then moved completely round the diagram clock-wise and brought back to the indentation. The wheel then indicates the area of the diagram. But if now the tracing point is moved vertically upwards against the edge of the movable clip until the wheel again reads zero, and a fresh indentation made by pressing it on the card, the distance between this point and the previous indentation will be equal to the average height of the card, and, measured on the same scale as that for which the diagram was taken, will give, of course, the mean pressure.

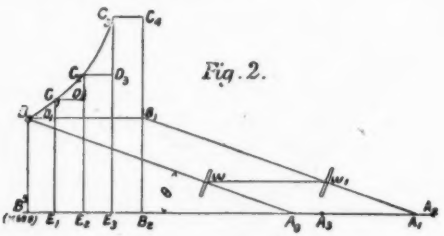


Fig. 2.

The theory of the instrument is simple. In the diagram, Fig. 2, let A_0B_0 denote the initial position of the straight line joining the tracing point of the instrument and the point which runs in the groove. Let L be the length of this line, and suppose the point B_0 to move horizontally to B_1. Then the area moved over by the line is, of course, the rectangle $A_0B_0B_1A_1$, which is on the same base and between the same parallels as the rectangle $B_0B_1B_2B_3$. Let θ denote the angle between the line A_0B_0 and the horizontal. Then the area swept out is likewise equal to

$L \sin \theta \times S$, where S denotes the horizontal displacement of the pointer, and in this case equal to B_0B_1, and L is the distance A_0B_0, *i.e.*, the length of the arm of the instrument. Now the axis of rotation of the measuring wheel of the instrument is parallel to the line A_0B_0, and hence the wheel will rotate in exactly the same way as if its axis of rotation coincided with A_0B_0, and it will be convenient to consider its axis as thus coinciding.

Thus let W represent this wheel, then when A_0B_0 has been displaced to A_1B_1, W will have been displaced to W_1. Let us resolve this displacement along the bar and at right angles to it. The first will be obviously $S \cos \theta$, and this component, being parallel to the axis of the wheel, cannot cause rotation. The other component will be $S \sin \theta$, and being in the direction of rotation of the wheel, will cause the latter to turn round as it moves over the paper on which it runs through a length of its circumference equal to this. But, as shown above, the area swept out by the bar was $L \sin \theta \times S$, and therefore the area swept out is also equal to $L \times$ the rotation of the wheel. Now consider the tracing point to move from B_1 to B_2. During this period the wheel will revolve through a certain angle, say ϕ. On reaching B_2, let the tracing point be moved up to B_3. The motion now is parallel to the axis of the bar, and hence the wheel does not revolve. Finally let the tracing point move back to its original position B_0. During this motion the wheel will obviously revolve through the same angle that it did in moving from B_1 to B_2, but in an opposite direction, thereby cancelling the rotation then added. Hence the final reading of the wheel at B_0 is proportional to $S \sin \theta$. But, as already shown, the area $B_0B_1B_2B_3$ is equal to $L \sin \theta \times S$. Hence the reading of the wheel is proportional to the area swept out by the tracing point when this area is a rectangle, the gist of the proof being that it is only horizontal motions of the tracing point in Fig. 2, which leave a permanent record on the wheel, all the vertical motions cancelling each other's effect on the wheel when the pointer is brought back to its initial position.

Next take the case of a figure having one or more curved sides, such as $B_0C_3C_4B_2B_3$. Then approximately the area of this figure

is equal to that of the rectangles shown, and will be exactly so if we take the rectangles small enough. Then, for convenience, assume that this time we start from the point B_3, and move the pointer round the small rectangle $B_3B_0D_1E_1$ back to B_3, then it follows, from what has gone before, that the reading of the wheel will now give us the area of this small rectangle, but the motion from E_1 to B_3 is in the direction of the axis of the wheel and does not cause it to rotate, hence the wheel will read the same at E_1 as at B_3. Let this reading be R_1. Bring back the tracing point to E_1 and describe the rectangle $E_1C_1D_2E_2$. Then on the pointer reaching E_1, the additional reading R_2 will be the area of this rectangle, and the total reading will be equal to the total area described from the commencement. Proceeding in this way for the remaining rectangles, it is obvious that when the pointer is brought back to E_3 the reading of the wheel is proportional to the total area described by the point, and bringing this point up to B_3, the point at which we first started, does not, as already explained, affect the reading. Now, as already explained, horizontal motions of the tracing point leave no permanent record on the wheel when the instrument is brought back to its original position. Hence we should have got the same results if the tracer had been taken along the course $B_3B_0D_1C_1C_2D_3C_3C_4B_2B_3$, and by choosing the rectangles small enough this course can be made to coincide with the curved course along B_0C_4. Hence, finally, when the tracing point is moved over the boundary of an area, the reading of the wheel is proportional to the area.

The reason why moving the instrument up from its final position, as described in explaining its use for indicator diagrams, against the movable clip till the reading of the wheel is canceled, gives the mean height of the diagram, is obvious. As the tracer moves up, the arm, as explained above, will describe a parallelogram, the area of which is equal to the reading canceled on the wheel. And, as shown above, this parallelogram is on the same base and between the same parallels as the rectangle formed by drawing horizontal lines from clip to clip through the two indentations made by the pointer. This rectangle, therefore, is equal in area to the diagram and has the same length, viz: the distance

between the clips. Hence its height is equal to the mean height of diagram.

[In connection with the general demonstration of the Amsler planimeter given above, it may be remarked that, as the Coffin averaging instrument is simply a special form, its demonstration may be given simply as a corollary of the general demonstration.

It will be noticed that the length of the arm carrying the fixed point does not enter in the expression for the area. Hence this arm may have any length. If it is made infinite, the joint will move in a straight line. This is what is done in the Coffin instrument, so that it is simply an Amsler planimeter whose arm a is of infinite length.—EDITOR.]

H. M. S. *SPEEDY.*

Reprinted from "Engineering."

There was launched at Chiswick, May 18, a vessel remarkable in more than one respect. H. M. torpedo gunboat *Speedy* is, in the first place, the largest vessel built above bridge—on the River Thames, at any rate—within modern record. There is a tradition that forty years ago or so an iron ship was built on this very spot, but the tradition is shadowy, and probably the "ship," if ever built, was at most a barge, for the site of Thornycroft's works was originally a barge-building yard. There is no fear of contradiction, however, in saying that the *Speedy* is the biggest steam vessel ever built above London Bridge. A few years ago it would have been impossible to have taken a vessel her size, over 800 tons, through the bridges, even if she had been built. Both Putney and Battersea Bridges—those picturesque old wooden structures which the artist regrets, even if the bargee rejoices in their removal—would alone have proved an effectual barrier. As it is, there is little enough room to spare between the intrados on some of the bridges and the bottom of the river, and the passage of the *Speedy* from Chiswick to open water will be an interesting performance—more interesting, perhaps, to an outsider than to those intimately concerned in the success of the proceeding. Hammersmith Bridge will be the most difficult passage, and that, of course, is a suspension bridge, so there is plenty of room laterally; it is the vertical distance that has to be considered. From the bottom of the river to the bottom of Hammersmith Bridge there is a distance of 31 feet 6 inches. This is less than the height of the top of the *Speedy's* conning tower (as erected finally) from her keel plate. With the conning tower on its side, however, there would be a distance of

2 inches between the bottom of the vessel and the bottom of the river, supposing the tide were such that the conning tower were 6 inches from the bottom of the bridge; that leaves a clearance of 8 inches all told, and Messrs. Thornycroft very wisely considered that would be hardly sufficient margin of safety. It has, therefore been determined to send the conning tower down as a separate parcel. The highest part of the main structure of the *Speedy* will then remain her forecastle deck, which is raised 7 feet above the upper deck. The greatest height required will be 25 feet, which is the vertical distance from the lowest part of the ship, that is the bottom of her rudder, to the highest fixed structure. This gives a clearance of 6 feet 6 inches, which may be pronounced sufficient.

Once through Hammersmith bridge, the vessel will have passed her chief difficulty; but there are other considerations. In order to get the depth of water in the river and the clearance under some of the bridges right, relatively to each other, one particular height of water has to be selected, and this naturally necessitates passing at a certain state of tide. Supposing this were half ebb at any given bridge, there might be too little depth of water—say at reaching Putney bridge—and the vessel would have to wait there until the tide flowed again. If, on the other hand, the passage of Hammersmith bridge were made at half flood, the water would have risen possibly so high by the time Putney bridge was reached that the height of the vessel out of water would be too great to pass under the bridge, although the draught of water would be ample. If this were not the case at Putney, it is certain it would be elsewhere, probably at Westminister, which is, we believe, the next lowest bridge after Hammersmith.

We have said enough, however, about the passage of the vessel down the river, which is not to take place yet, and we will proceed to describe the craft herself. Before doing so, however, it may be interesting to briefly glance at the evolution of this vessel from the early torpedo boat, undoubtedly her ancestor. The first torpedo boat of the modern type was built at Chiswick, by Messrs. Thornycroft, for the Norwegian government. She

was 58 feet long by 7 feet 6 inches beam; was constructed of steel, and had compound surface-condensing engines. This vessel was built in 1876. It was not for some time after that the British navy possessed a torpedo boat; this was the historic "*Lightning*." She was 81 feet long by 10 feet 10 inches beam, and was 32½ tons displacement. The next notable step made by the Chiswick firm in the development of the torpedo boat was in a vessel they built for the Italian government. She was 100 feet long and 11 feet 8 inches wide; her displacement was 34½ tons, and she was constructed about the year 1880. In 1885 the British government ordered twenty-five first-class torpedo boats from Messrs. Thornycroft under pressure of a war scare. These were 125 feet long by 12 feet 6 inches beam, and were of 63½ tons displacement. The *Ariete*, built for the Spanish government, was the next notable craft. She was 147 feet 6 inches long by 14 feet 6 inches beam, and displaced 98¾ tons. Last year some boats were built for the Brazilian government at Chiswick, which were 150 feet long by 14 feet 6 inches beam, and were of 103½ tons displacement. At the present time there are building alongside the slip from which the *Speedy* has just been launched, three new torpedo boats for the British government. These vessels are 140 feet long by 15 feet 6 inches beam, greater breadth and less length, it will be seen, than the Brazilian boats, but their displacement is considerably more than that of the latter, being 125 tons. This increased ratio of beam to length in the English boats will certainly cause a falling off in speed, but the dimensions are rendered necessary by the increased weight carried on the prescribed length, according to the regulations of the English naval authorities. The Brazilian boats were 25-knot craft; the English boats are guaranteed for 23½ knots. As a final development of what may be described as the boat contingent of the torpedo fleet—the *Speedy* being an undoubted ship—we have the 27-knot "destroyers," two of which are now being constructed at Chiswick. These craft are to have a speed of 27 knots as a minimum—how much more remains to be seen. They are 185 feet long by 19 feet beam, and their displacement is 220 tons. We will now proceed to our description of the *Speedy*.

H.M.S. *Speedy* is 230 feet long by 27 feet beam, and has a depth amidships of about 15 feet. Her displacement complete will be 810 tons, but as launched she is 615 tons displacement. The load draught will be about 8 feet 10 inches. The twin-screw torpedo gunboat type, to which the *Speedy* belongs, was initiated by the *Rattlesnake*, built at Laird's. This vessel was, however, but 550 tons displacement. The class was advanced by the *Sharpshooter* design being introduced; the latter vessel was constructed at Devonport, and engined by Bellis; her displacement was 735 tons. The *Jason* gives her name to the next advance in the class; she and her sister ships, the *Jaseur* and *Niger*, were constructed at Barrow, and her displacement is 810 tons. The *Onyx* and *Renard* have been built at Birkenhead. The remaining vessel of this class is the *Speedy*. In general appearance afloat she is somewhat peculiar. She has three funnels, two pole masts, and there extends aft from the stem, for about one-third the length of the ship, a raised forecastle deck, which is about 7 feet above the upper deck; the latter being, in fact, the main deck, as it is the only one running right fore and aft. For the rest of the distance aft, until about one-fourth the length of the ship from the stern is reached, there is a flying bridge, and from the termination of this to the stern there is no erection above the upper deck; the freeboard to the upper deck is about 6 feet, and, therefore, there is about 13 feet above water forward, as far as the forecastle deck extends. The chief object of the flying bridge is to give access to the different compartments of the ship in bad weather, when the main deck would often have a good deal of water upon it, and the hatches would have to be battened down. In the center part of the vessel is the machinery space, and here there is but a single deck, namely, the upper deck, which extends in an unbroken line from the stem to the stern. The forward machinery space bulkhead is at the place where the forecastle deck terminates, and it also forms a termination to a lower deck. There are, therefore, for the first third of the vessel—that is, up to the forward machinery space bulkhead—three decks; the forecastle deck, the upper deck or main deck, and the lower deck. In the part aft of the machinery space, there are two

decks—the main deck and the lower deck—the latter forming the floor of the cabins. The crew are berthed forward, upon the lower deck, and beneath this the structure is minutely subdivided into water-tight compartments, which form magazines, stores, torpedo rooms, and machinery rooms for auxiliary machinery. This lower deck is watertight, having coamings round all openings, and water-tight hatches. There is, therefore, practically a deep double bottom forward when the hatches are closed, and the same remark applies to the after portion of the vessel. Of course, in action, the hatches would have to be open in order to get up ammunition, &c. In the midships part there is nothing but the single skin of the vessel. The height of the lower decks is 8 feet 6 inches from the bottom, which brings them just a little above the water line. The machinery space is inclosed by bulkheads, with water-tight doors, and these bulkheads go from deck to bottom. In regard to the other parts of the ship, there is very considerable subdivision, but as the bulkheads are not carried through in the same plane, it is difficult to form an idea, from an inspection of the vessel, how all the compartments are arranged. It may be said generally that the provision against sinking by damage to the hull structure is very complete. There are two boiler rooms and two engine rooms, and these can be separated from each other by means of water-tight doors and bulkheads. The bow is especially well subdivided.

The *Speedy* has been built to the design of Dr. W. H. White, and displays the beautiful form of hull which characterizes the under-water shape of all the creations of the director of naval construction. Our readers will doubtless remember the bow and stern models of the *Blenheim* and *Blake*, which were exhibited in the Naval exhibition. The *Speedy* very much resembles these. There is not much to be said in regard to the constructive details of the ship. The design is essentially modern and very light. The plating is lap streak and lap butts, and is certainly not overdone in the matter of thickness. The riveting has been done hot; the size of rivets—mostly ½ inch—being above that which is practicable in cold riveting. There is, of course, as in all Navy vessels, a flat plate keel and an intercostal keelson. The

framing is of the usual type of angle-bar, and there are bulb beams, with welded knees. The stem is steel forged, and the stern frame is a steel casting. The rudder has a cast-steel frame, and is steel-plated and filled with wood, as usual. In shape the rudder is the now fashionable partially balanced and partly under the bottom type—that is to say, the part abaft the sternpost is carried deeper than the bottom end of the sternpost, and then is prolonged forward of the axis upon which it turns.

There are two sets of triple expansion engines, having cylinders 22 inches, 34 inches, and 51 inches in diameter, by 21 inches stroke. They are designed to run at 250 revolutions a minute, with a safety valve loaded to 210 pounds to the square inch. The air pumps are worked in the usual way, by side levers from the low-pressure engines; they are single-acting, 18 inches in diameter by 8¾ inches stroke. The high-pressure cylinders have piston valves; the intermediate and low-pressure cylinders have flat valves, balanced, the exhaust steam passing out through the center of the valve. The cylinders are not jacketed. The steam-reversing gear is what is known as the "all-round" type, and is arranged so that the engines are kept automatically going alternately ahead and astern for a few turns, when the ship itself has stopped. This is to keep the cylinders warm and maintain the vacuum. In order to avoid the effects of the expansion of a long cylinder casting, a circumstance which tends to throw the guides out of line, the cylinders are cast separate, and connected by a system of cross-bracing, the details of which have been very carefully worked out, in order to adequately provide against the stresses induced. The slipper guides are of forged steel with water-tubes. The screw shaft is hollow and of fluid-compressed steel. The condensers are of the cylindrical type, entirely of brass. There are two fans for forced draft driven by engines of the usual type direct; one is placed in each stokehold. In general design, the engines are very open and accessible. Steel has been used in all parts of the construction where it is admissible. The length of journals and bearing surfaces of all rubbing parts are large in these engines, the influence of torpedo-boat practice being clearly discernible here. A novel point

about this vessel is that all the handles required for manœuvring the ship are grouped together, so that really she could be managed by one man if required.

The lubricating arrangements are worthy of attention, being ingeniously devised. There is a receptacle which is fed from an oil tank above. From this receptacle oil is allowed to drip into a cup, from whence it is carried to the bearings by means of a suitable pipe, the drip of oil being controlled by a screw valve with a solid taper plug. In cases where the opening of the valve cannot be adjusted finely enough to give no more than the required supply, as in running at easy speeds, there is an arrangement by which oil is forced into another receptacle above, the head obtained by the tank being sufficient for this purpose. Syphon wicks are provided in this second receptacle, and in this way a slower feed is obtained than can be got from the drip from the screw plug. To alter from slow to fast feed of lubricant it is only necessary for the attendant to open a valve. The arrangement is especially suitable for war vessels where the ranges of speed are considerable.

We now come to what is really the most important feature in this vessel, namely, the boilers. These are of the now well-known Thornycroft water-tube type, of the same description as fitted in the torpedo-boat *Ariete*.* The *Ariete*, it will be remembered, had two boilers ; the *Speedy* is to have eight—four in each stokehold. They are alike in all respects. Each one has 1,840 square feet of heating surface and 25½ square feet of grate surface. The tubes are of steel and are from 1⅛ inches to 1¼ inches in diameter, the largest being nearest the fire. The working pressure is to be about 200 pounds to the square inch. In the other ships of the *Jason* type the indicated horse-power is said to be 3,500, which is estimated to give a speed of 19.25 knots. With the same dimensions and displacement the *Speedy* is to have a contract power of 1,000 additional units, namely, 4,500 indicated, and this is to give her a speed of 20.25 knots—that is, one knot extra. The space allotted for machinery is, we believe, the same in the *Speedy* as in the other vessels. These figures give a

* See " Engineering," vol. xliv, pages 81 and 105.

measure of the advantages that are expected to be obtained by the use of the Thornycroft boiler, and it remains to be seen how they work out in practice. Taking the performance of the *Ariete* as a type and in the light of what is already known of the torpedo gun-boat type of boiler—which is of the wet-bottom fire-box locomotive type, with a divided furnace—we think there is little doubt that Messrs. Thornycroft will fulfill their contract with greater ease than the contractors of the other vessels. In the *Jason* there are four boilers; the total heating surface is 6,388 square feet, and the total grate surface 472 square feet. In the *Speedy's* eight boilers there are 14,720 square feet of heating surface. The engine cylinders are of the same diameter in the *Speedy* as in the other vessels, and the piston speed is estimated to be the same. There is, therefore, the additional 50 pound pressure as a source of power. What will be the actual number of revolutions on trial, of course, remains to be seen, and it depends on the size of ports and points of cut off. The trials of the *Speedy* will certainly be watched with the greatest interest. The stokeholds of the vessel are by far the most comfortable and commodious we can remember for ships of this description—we might almost say of any description. It is possible to walk round each boiler, and any part of the casing can be removed for examination of the tubes. The boilers, it should be stated, were built in the stokehold, the deck having been completed before the operation was carried out. This is a great advantage, not only in the case of renewing boilers, but in the original building of the vessel, as the constructors do not have to wait for the engineers. With regard to the renewal of tubes of this boiler, we are informed that an inner tube has been taken out and the holes plugged without disturbing the outer rows. A difficulty often raised in working pipe boilers in groups is the trouble in distributing the feed. There are two Weir's feed pumps for ordinary feed purposes, and the feed pipes are kept under an excess of pressure. Each boiler has a valve for regulating the feed, and Messrs. Thornycroft anticipate there will be no difficulty in this direction. The arrangement for making either pump serve either or both groups of boilers is well planned, the whole arrangement being controlled by means of two subsidiary valves.

The armament will consist of two 4.7 inch quick-firing guns, one mounted on the forecastle deck forward and the other aft. They will both be protected by shields. There will also be four 3-pounder quick-firing guns. A bow torpedo discharger is fitted, and there will also be two launching carriages. The usual search-light will, of course, be fitted.

The *Speedy* was launched yesterday afternoon, the ceremony being performed by Lady George Hamilton. As there is no dock into which the ship could be taken when launched, special arrangements had to be made, and for some time past Messrs. Thornycroft have been engaged in dredging a hole off their works in order to prevent the vessel grounding at low tide. The *Speedy* was unusually complete as launched, having her funnels up and her masts stepped, whilst the machinery was all in position.

THE SINKING OF H. M. S. *VICTORIA.*

On the afternoon of Thursday, June 22d, during fleet evolutions in the eastern end of the Mediterranean, the *Victoria* was rammed by the *Camperdown* and sank in about ten minutes, bow first, and after having capsized. The following is the official report of the disaster by Rear Admiral Markham, commanding the second division of the fleet:

"When about five miles from the anchorage off Tripoli, the signal was made at twenty minutes past two in the afternoon to form columns of divisions in line ahead, disposed abeam to port, the columns to be six cable lengths apart.

"We proceeded in this formation until twenty-eight minutes past three, when the signal was made from the *Victoria* to the first division to turn sixteen points to port and to the second division to turn sixteen points to starboard. As the columns were only six cable lengths apart, it was not, therefore, in my opinion, possible, within the manœuvring distance, to execute such an evolution. I directed the flag lieutenant to keep the signal, which we were repeating, at dip, as an indication that the signal from the *Victoria* was not understood. I then directed him to semaphore, "Do I understand it is your wish for the columns to turn as indicated by the signal now flying?"

"But before my order could be carried out, the Commander-in-Chief semaphored me to know what I was waiting for. It then struck me that he wished me to turn sixteen points, as indicated by the signal, and it was his intention to circle round the second division, leaving them on the port hand. Having the fullest confidence in the great ability of the commander to manœuvre the squadron without even risk of collision, I ordered the signal hoisted as an indication that I understood.

"When the signal was hauled down, the helm of the *Camperdown* was put hard-a-port; at the same time the helm of the *Victoria* was starboarded. I watched very carefully the helm of the *Victoria*, as indicating the purpose of her signals.

"As the two ships turned towards each other, and seeing that the helm of the *Victoria* was still hard-a-starboard, I directed the captain of the *Camperdown* to go full speed astern with the starboard screw in order to decrease our circle of turning.

"Seeing that a collision was inevitable, I then ordered him to go astern full speed with both engines, but before our speed could be materially checked, the stem of the *Camperdown* struck the *Victoria* on the starboard bow about twenty feet before the turret and crushed into the ship almost to the center line, the fore-and-aft lines of the ships at the time of collision being inclined toward each other at an angle of about eighty degrees."

The vessels were interlocked for about two minutes, but the *Camperdown* then succeeded in withdrawing her ram. Admiral Tryon, however, apparently did not believe that the *Victoria* was in serious danger. He even forbade the lowering of boats by the other ships, who realized the situation and were prepared for the worst. Orders were given to drive full speed for the shore, but before a mile had been traversed it was evident that all was lost. The order was given for each one to save himself, and many jumped overboard, but while the majority were still below, the vessel suddenly heeled over and remained floating bottom up for about three minutes. Then she plunged, bow foremost, to the bottom.

The following comments are from editorials in "Engineering:"

It will not be known for some time how many lives have been lost by this terrible calamity. The first report gave the number as about 370, and this will probably turn out to be a fairly close estimate. The loss of life was enormously multiplied by the suction caused by the sinking of the ship, as is nearly always the case when a big vessel goes down suddenly. It would seem that the inrush of water forward so weighted down the bows that the stern was lifted right out of water, the ship going down head first, almost like a whale sounding. The fact is quite conceivable, and

it will be remembered that in the case of a torpedo-boat which was sunk during the last manœuvres, a similar thing occurred.

We do not, for our own part, suppose that the boilers of the ship actually exploded. We know it is often stated that this accident occurs when ships founder, but this is due to a popular delusion. No doubt vessels themselves sometimes blow up owing to the pressure of the atmosphere, and possibly the large volumes of steam suddenly generated by the inrush of sea water to the boiler furnaces.

To us, as engineers, the catastrophe is especially terrible; still we cannot but look with pride upon the part played by the engine-room complement. The loss of life in the engineering department is a commentary on the devotion displayed by the men of the staff. In the *Victoria* the number of combatant officers above the rank of midshipman, not including the Admiral, was fifteen, viz: captain, commander, seven lieutenants, staff commander, three marine officers and two sub-lieutenants. Happily, of these fifteen, only one was lost; their duties not calling upon them to place themselves in the positions of greatest danger. The number of engineer officers was six, viz: fleet engineer, two engineers and three assistant engineers. Of these six, five were lost. Out of ten engine-room artificers, six were lost; and out of 110 stokers and leading stokers, seventy-four were lost. These figures, of course, are approximate, and may require correction when the facts are more fully known. Undoubtedly, in a case such as this, the heroism of the occasion is with the engine-room staff. They have to dive below, whilst others work towards the deck. Their awful position in the event of the ship capsizing needs no comment, and the fact that the engineer officers and men of the *Victoria* braved these dangers in the discharge of their duty, and went to what they must have known was certain death, forms one of the most noble pages in all the glorious annals of the British Navy.

In the issue of July 7th, the following editorial appeared:

In our last issue we commented on the terrible loss sustained by the country in the sinking of the *Victoria* and the sacrifice of so many lives. Since then fuller particulars have come to hand

in the shape of Admiral Markham's dispatches. There is little doubt—in fact, it may be said there is no doubt—that the catastrophe occurred through an error on the part of the late Commander-in-Chief, Sir George Tryon. Knowing the great ability of the late Admiral, it is difficult to understand how he could have given an order such as he did, which must have resulted in the collision of the ships. The reports state that he had only that morning come off the sick list. What the nature of his illness was we are not aware, but we are compelled to think that he was in a state of weakness which incapacitated the proper functions of the brain. Most of us know that mental state in which physical weakness so reduces one that no effort of will can compel the mind to fix itself on one object; when memory seems for the instant to fail and facts lose their proper significance. Fortunately, this mental paralysis, which is the result of sudden stress on a mind weakened from physical causes, seldom happens to ordinary men when they are in a position to make the failure so terribly serious as in the case of the late Sir George Tryon. No doubt the late Admiral fell a victim to his own excess of zeal; and his desire not to spare himself has resulted in the loss not only of his own life, but of that of 358 fellow sailors.

According to Admiral Markham's dispatch, the course of events, briefly stated, appears to be as follows: The squadron consisted of the *Victoria*, *Camperdown*, *Nile*, *Dreadnought*, *Inflexible*, *Collingwood*, *Phœton*, *Edinburgh*, *Sans Pareil*, *Edgar*, *Amphion*, *Fearless* and *Barham*. The ships were formed in single column line abreast, and proceeding at a speed of about 8 knots. When within about five miles of the anchorage off Tripoli, the signal was made, at 2.20 P. M., to form columns of divisions in line ahead, disposed abeam to port; the columns to be six cables apart—that is to say, the ships were formed in two lines, each vessel having another abeam of her; the distance between the two being 1,200 yards and the distance between each of the ships in the lines 400 yards. Admiral Tryon then made the signal that the ships of the two lines should turn inwards towards each other. This was at 3.25 P. M., the first division being directed to alter

course 16 points to port and the second division 16 points to starboard, the leaders together and the rest in succession.

The evolutions, as we have stated, with the ships only six cables apart, could hardly fail to result in a collision. Admiral Markham recognized this, for he kept the answering signal at the dip, indicating that he did not understand, and had given orders for a signal to be prepared which could only be looked on in the light of a remonstrance. Before, however, the latter was hoisted, the Commander-in-Chief signalled by semaphore to the *Camperdown* to proceed with the evolution, and Admiral Markham had no choice but to obey.

The conduct of the second in command has been called in question by some critics, who evidently are not acquainted with the implicit obedience required in the Royal Navy to an order deliberately made by a superior officer. No doubt, had Admiral Markham refused to obey, it would have been better in this case; but, on the other hand, had he done so he would undoubtedly have been severely censured. Indeed, there are those who appear desirous to fix the blame on Admiral Markham for the hesitation he did show. Nothing but the fact that an officer has lost command of his senses can warrant a subordinate in refusing obedience. Admiral Markham very properly took this view of the situation, and concluded that the Commander-in-Chief proposed some tactic which could have been safely carried out, and his refusal to obey the signal might have resulted in the very thing he was anxious to avoid—viz: the collision of the ships.

Both the *Victoria* and the *Camperdown*, therefore, turned towards each other, the flagship's helm being put hard-a-starboard, and that of the *Camperdown* hard-a-port. It should be noticed that in discussing the manœuvres beforehand, the late Commander in-Chief had stated that he intended to form the fleet in two divisions, the columns to be six cables apart; but the staff commander had suggested that eight cables would be a better distance, to which the Admiral had assented. Nevertheless, the signal was made by the Admiral's order for the distance to be six cables. This was noticed by Commander Hawkins Smith, of

the *Victoria*, who sent down to inform the Admiral that six cables were flying, but the Admiral determined to leave matters as they were. The fatal results that followed are but too well known. There seems to be no doubt but that the officers of the *Victoria* were alive to the danger that would follow, but the spirit of discipline prevented remonstrance, until the terrors of a collision were so imminent that Captain Bourke, of the *Victoria*, asked permission to reverse the port screw, and immediately afterwards both engines were put full speed astern.

In the *Camperdown*, when Admiral Markham saw that the *Victoria* was turning inwards instead of going under his stern, as he anticipated she would do in spite of the signals, the order was given to go full speed astern with the starboard screw so as to decrease the circle of turning, and, when collision was inevitable, both engines were put full speed astern, as in the case of the *Victoria*. This reversing of the engines in both ships was, however, undertaken too late to do much to check the way of the vessels, and the *Camperdown* struck the *Victoria* about 20 feet before her turret, the angle the two ships bore towards each other being about 80 degrees. A chief petty officer, who was in his mess right forward and who was saved, stated that the *Camperdown's* bow came right through into the *Victoria* as far as the chain lockers, and burst in the bulkhead between the fore mess deck and the stokers' mess deck.

Remembering that the *Camperdown* was originally only steaming about 8 knots, and that both engines were reversed at the time of the collision, it is difficult to estimate what would have been the effect had she struck the *Victoria* on her unarmored forward part at anything like full speed. It would almost seem as if she would have sheared the bow of the ship right off in spite of the armored deck. Captain Bourke, in his report to Rear-Admiral Markham, states that, when collision was inevitable, orders were given to close watertight doors on the *Victoria*. This order, Captain Bourke says, was carried out, and he left the deck, by the Commander-in-Chief's order, to see if all doors were closed and up to what bulkhead the ship had filled. Some of the doors, Captain Bourke says, were closed; but the whole sad

business took so short a space of time that it is very doubtful whether the captain's statement would have been made if he had been acquainted with the whole of the facts.

Possibly this mishap will lead to a revision of the orders in regard to the closing of watertight doors during steam tactics. Although the *Victoria* is the first ship that has been sunk in this way, we hear of many close shaves on previous occasions that have occurred during steam tactics and on other occasions, and it is certainly desirable that the closing of the watertight doors should not be left until the last few seconds when collision is inevitable. One knows the objection all people, more especially sailors, have to taking precautions against accident, and nearly all men prefer to risk a possible serious calamity to the certainty of small present inconvenience.

The closing of watertight doors is enjoined by the Admiralty regulations, but we believe nothing is said about their being kept closed; and, having been reported as closed, they are immediately opened. There is some security even in this evolution, if properly carried out, for the fact is ascertained that the doors are in working order; but more security is required when ships are about to perform intricate manœuvres, where an error in judgment—as shown in the present unhappy circumstance—or a failure in machinery, may lead to the sacrifice of many valuable lives and the loss of large sums of money to the country.

The injuries received by the *Camperdown* herself were not insignificant, and, although we have very bare accounts of them yet, it would seem that the ship would almost have been put out of action by her encounter with the *Victoria*, even though it was made under the most favorable circumstances for the ramming vessel. Admiral Markham states that it was two minutes before the *Camperdown* was able, although going full speed astern with both engines, to get clear of the *Victoria*, and it would seem that the danger sometimes foreshadowed, of a rammed vessel causing the destruction of her assailant by the latter being unable to get clear, is by no means visionary. The watertight doors on the *Camperdown* were shut, it is stated, before the col-

lision occurred; perhaps this statement will require revision, but, at any rate, the deck forward was only one foot above water. She had a jagged hole in the port bow, extending from the stem to an extreme distance of 10 feet abaft, and from 12 to 18 feet below the upper deck; the lower edge being just above the armored deck. The stem was broken above the ram, and the stempiece was separated from the plating on the starboard side for a depth of 10 feet below the water line. The carpenters' store-room, the paint-room, fore ballast-room, boatswain's store-room, submarine mining-room, tank-room, capstan engine flat, and also the patent fuel space on the port side of the chain lockers, were all filled, but several of these compartments were afterwards pumped out dry.

[Inasmuch as there has been a good deal of discussion as to the watertight subdivision of the *Victoria*, claims being made that her capsizing was due to the presence of a middle-line bulkhead, the annexed illustration will be of interest.—EDITOR.]

The "Iron Age," of New York, publishes in its issue of August 17th some highly interesting extracts from a letter to the editor, written by Captain Cooper Kirton, of Valletta, Malta, which are as follows:

When the *Victoria* was first commissioned, one of our best fighting officers remarked that, had he to engage her, he would direct all his quick-firing guns at her unprotected ends, riddle the water line, when, as soon as the water flooded the protective deck, she would, with her low freeboard, inevitably capsize. This common-sense view of her stability has been borne out by the facts, for, with only half of her protective deck flooded, the ship has capsized.

The general opinion is that the cause of the *Victoria's* loss was water-tight doors left open. This is entirely untrue, for the closing of the water-tight doors hurried the loss of the ship and lost us a large number of valuable lives. This particular statement I will proceed to prove.

Fig. 1 Profile

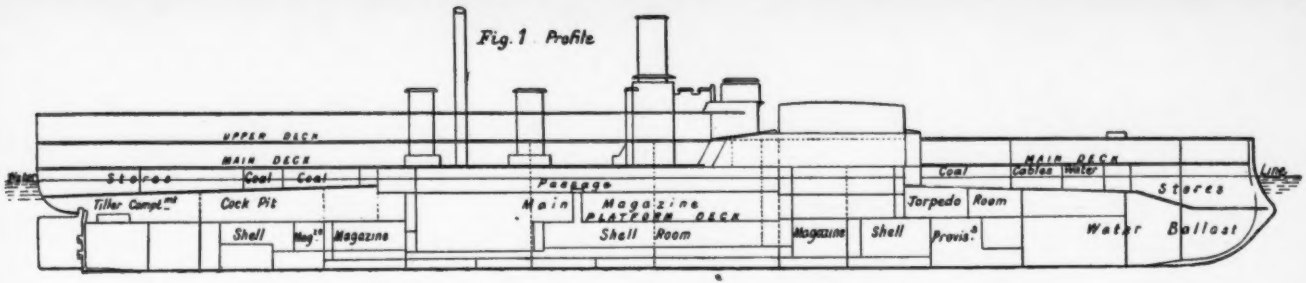


Fig. 2. Plan of Hold

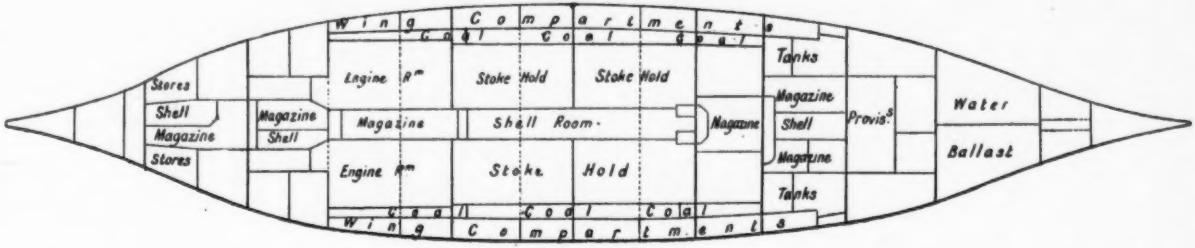
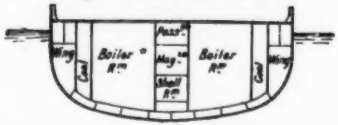


Fig. 3. Midship Section.



When, after the collision, Admiral Tryon found that the engine rooms and stokeholds were intact, the water-tight doors closed, and over three-fourths of his ship sound, he countermanded the boats of the fleet and headed the ship for the shore to beach her. He thought he had a ship under his feet, not a death trap, and his men were so impressed with the notion of unsinkableness that many, when warned, refused to come on deck. The whole of the engine-room staff on watch perished to a man, busy driving the ship to shore and expecting to get there.

Now we will change the scene. We will suppose that this vessel had not been in the state of magnificent discipline that she was, that the crew had rushed for the deck, leaving the water-tight doors to take care of themselves. The consequences would have been, stokeholds and engine rooms flooded, the ship would have been stopped, would have commenced to sink on an even keel, when the boats of the fleet would have had plenty of time to have saved all hands, even to the last man, the gallant and lamemted admiral.

What actually occurred was as follows, and I am afraid quicker than I can write it: Directly *Camperdown* tore out her ram *Victoria* took a list to starboard, the bow drooping. When she was started for the beach, being down by the head, to commence with, *she began to bore forward and tip aft.* The protective deck was rushed full up, the end of main deck filled, the dip and list rapidly increased until she, losing the stability of her full after water line, was floating upon what might be termed a raking transverse section, a position of utter instability, when over she went. The final plunge was, I may say, instantaneous.

So little idea had the people in the engine-room of such a catastrophe that a few moments before she turned over the engineer sent an artificer on deck to know why they were letting go the anchors when the ship was steaming ahead, this letting go the anchors being the cables running out through the vessel's bottom, she having been cut right into to the chain locker.

The lesson to be learned from this appalling calamity is that should another of these costly coffins be struck in the same manner the only way to get her beached would be to lock the

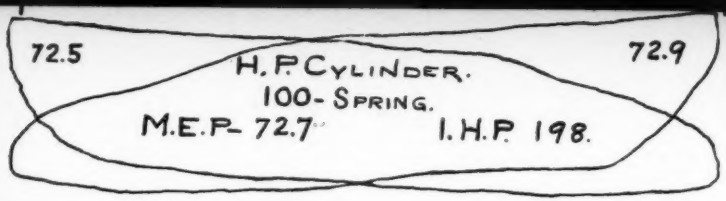
helm amidships, tell off a vessel to make fast to each quarter, and tow her in stern first.

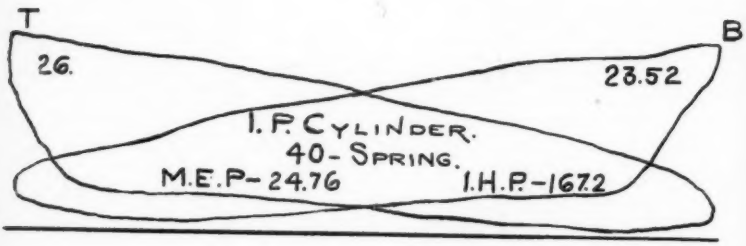
The *Camperdown's* ram struck *Victoria* nearly at right angles, say about 80 degrees, and cut nearly into her middle line just as if she had been made of cheese. So much for ramming. The feeling aboard the *Camperdown* was as if they were cutting into a soft sandbank; there was no jar felt, and the engines worked afterward as if nothing had happened.

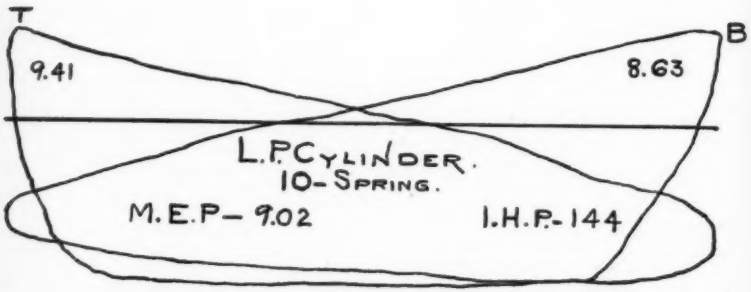
The damage to *Camperdown* was stem, 15 by 5 feet, broken short off above ram and turned to port 18 degrees; upper part of stem crushed in, making an opening of about 15 feet long by 10 or 11 feet wide; the plates on port side were crumpled up like paper. This side suffered most. A large hole, 9 by 10 feet, being ripped out, commencing at break of stem and running aft just above protective deck. The frames showed the effects of the first blow and subsequent dragging clear and were twisted out of recognition. The ram was practically uninjured and could have rammed another vessel. It was all wrought work, no casting, and admirably strengthened by heavy horizontal ram plates. This ship will be thoroughly repaired and be afloat early in September.

The defect in bows and rams, as at present constructed, is that they are supposed to ram and rip up a vessel under water, the bow above not being affected. Instead of which the vessel built for ramming cuts into another so easily that she never stops until choked off by the crushing up of her own top sides. Nothing, not even the strongest ironclad that was ever built, could withstand ramming; the thickest armor would be simply driven in.

The damage to *Camperdown* shows that the stem above the ram ought to be worked thicker and deeper and the plating made thicker, so that the stem would take the blow and the edge of plating be covered. The stem plating of *Camperdown* was simply sheared off for want of this precaution. The stem and frames should also be backed by heavy stringers, capable of wedging into any ordinary top side without much damage to the rammer.







TOTAL I.H.P- 509.2

CARDS No 4 — 5.05 P.M.

STEAM PRESSURE	155
REVOLUTIONS	162
1ST RECEIVER	45
2ND RECEIVER	7
VACUUM	25

REV. STR. "HUDSON"

CYLINDERS- $\frac{13" - 21" - 32\frac{1}{4}"}{24"}$

DELAWARE RIVER — JULY 31ST 1893.

THE OFFICIAL TRIAL OF THE REVENUE CUTTER *HUDSON.*

By Assistant Engineer Chas. A. McAllister, U. S. R. C. S.

The *Hudson* was built by John H. Dialogue & Son, of Camden, N. J., the contract price for her construction being $37,000. She is a small vessel, and is intended for boarding duty in New York Harbor, relieving the revenue cutter *Washington* which will be transferred to Philadelphia. The quarters for the officers and crew are roomy and convenient. Forward, under the pilot house, there will be a large room fitted up for the accommodation of the customs inspectors while on board the vessel.

HULL.

Material		Iron.
By whom built		J. H. Dialogue & Son.
When built		1892–'93.
Length, over all		97 feet 6½ inches.
Length on L.W.L		90 feet.
Beam, moulded		20 feet 6 inches.
Depth in hold from top of main deck beams to top of floors		10 feet 3 inches.
Draught, forward	For L.W.L.	7 feet.
Draught, aft	For L.W.L.	8 feet 10 inches.
Displacement, tons		174.

The wrought-iron plating used for the hull was subjected to a tensile test of 45,000 pounds per square inch, with an elongation of 25 per cent. in a length of 8 inches. The bar keel is of wrought iron 5½ inches by 1½ inches, and the stem is of the same dimensions. The frames are of 2½ inches by 2½ inches by 5-pound angles spaced 22 inches from center to center. The garboards, sheer strakes and the strakes next below the sheer strakes are of 15-pounds plating, and the other strakes of 12½-

pounds plating. The deck beams are 3 inches by 3 inches by 7¼-pounds angles, with a crown of 4 inches in 20½ feet.

MACHINERY.

The engine is of the vertical-inverted, direct-acting, triple-expansion type, with three cylinders, supported on wrought-iron columns in front and cast-iron columns at the back. There is one piston valve for the high, and double-ported slide valves for the intermediate and low pressure cylinders, all worked by Stephenson link motion. The piston valve is solid and takes steam at the ends. The air and circulating pumps are independent of the main engine and worked by one steam cylinder. The boiler is of the Ward tubulous pattern of the size known as P. 30 with Q fire box.

ENGINE.

Cylinders, number		3.
Cylinders, diameter of H.P.		13 inches.
Cylinders, diameter of I.P.		21 inches.
Cylinders, diameter of L.P.		32¼ inches.
Stroke of pistons		24 inches.
Valves, diameter of H.P.		6 inches.
Valves, length of I.P.		22 17/32 inches.
Valves, width of I.P.		15 inches.
Valves, length of L.P.		24 29/32 inches.
Valves, width of L.P.		26¾ inches.
Valves, diameter of L.P. balance piston		5 inches.
Valves, effective area of L.P. balance piston		18.64 square inches.
Area H.P. steam ports, maximum opening	Top	12.54 square inches.
	Bottom	13.7 square inches.
Area H.P. exhaust ports, maximum opening	Top	26.65 square inches.
	Bottom	22.32 square inches.
Area I.P. steam ports maximum opening	Top	24. square inches.
	Bottom	26.23 square inches.
Area I.P. exhaust ports maximum opening	Top	51. square inches.
	Bottom	42.7 square inches.
Area L.P. steam ports, maximum opening	Top	48. square inches.
	Bottom	52.46 square inches.
Area L.P. exhaust ports, maximum opening	Top	92.24 square inches.
	Bottom	73.49 square inches.
Valve stems, H.P., diameter		1⅜ inches.
Valve stems, H.P., diameter through valve		1¼ inches.
Valve stems, I.P., diameter		1¾ inches.
Valve stems, I.P., diameter thaough valve		1⅜ inches.

Valve stems L.P. diameter ..... $1\frac{3}{4}$ inches.
Valve stems L.P. diameter through valve ..... $1\frac{3}{8}$ inches.
Main steam pipe (5 inches diameter), area cross-section ..... 19.63 square inches.
Exhaust pipe from I.P. to L.P. ($7\frac{1}{2}$ inches diameter) ..... 44.17 square inches.
Exhaust pipe to condenser ($9\frac{1}{2}$ inches diameter) ..... 70.88 square inches.
Volume swept by H.P. piston per stroke ..... 1.84 cubic feet.
Volume swept by I.P. piston per stroke ..... 4.81 cubic feet.
Volume swept by L.P. piston per stroke ..... 11.34 cubic feet.
Ratio of net area of H.P. to I.P. piston 2.60
Ratio of net area of I.P. to L.P. piston 2.35
Ratio of net area of H.P. to L.P. piston 6.15
Piston rods, diameter ..... $2\frac{3}{4}$ inches.
Piston rods, length from piston to crosshead ..... 3 feet.
Connecting rods, length center to center ..... 50 inches.
Connecting rods, diameter of upper end ..... $2\frac{5}{8}$ inches.
Connecting rods, diameter of lower end ..... 4 inches.
Connecting rods, thickness (sides are faced) ..... $2\frac{5}{8}$ inches.
Crossheads, surface (10×8) ..... 80 square inches.
Crosshead pins, diameter ..... $3\frac{1}{2}$ inches.
Reversing gear, diameter of cylinder ..... 6 inches.
Reversing gear, stroke ..... $13\frac{1}{2}$ inches.
Reversing gear, piston rod, diameter ..... $1\frac{1}{16}$ inches.
Crank shaft, diameter ..... 7 inches.
Crank shaft, coupling disc diameter ..... $14\frac{1}{2}$ inches.
Crank shaft, coupling disc, thickness ..... $1\frac{1}{2}$ inches
Crank shaft, journals, diameter ..... 7 inches.
Crank shaft, journals, length ..... $6\frac{5}{8}$ inches.
Crank pins, diameter ..... 7 inches.
Crank pins, length ..... $6\frac{1}{2}$ inches.
Crank webs, width ..... $13\frac{1}{2}$ inches.
Crank webs, thickness ..... H.P., 4 inches; I.P., $4\frac{3}{4}$ inches; L.P., $5\frac{1}{2}$ inches.

PROPELLER AND SHAFTING.

The shafting is of the best wrought iron. The crank shaft is of scrap iron and built up. The propeller is of cast iron and solid.

Thrust shaft, diameter ..... $6\frac{1}{2}$ inches.
Thrust shaft, diameter of flanges ..... $14\frac{1}{2}$ inches.
Thrust shaft collars, number ..... 6.
Thrust shaft collars, diameter ..... $10\frac{1}{4}$ inches.
Thrust shaft collars, thickness ..... 1 inch.
Thrust shaft collars, distance between ..... 2 inches.
Thrust shaft collars, surface ..... 296.4 square inches.
Propeller shaft, diameter ..... 6 inches.
Propeller shaft, diameter of flange ..... $14\frac{1}{2}$ inches.

Propeller, number of blades..... 4.
Propeller, diameter..... 7 feet 6 inches.
Propeller, diameter of hub..... 16 inches.
Propeller, pitch, true screw..... 10 feet 6 inches.
Propeller, greatest width of blade (3 feet 3 inches from axis)..... 25⅜ inches.
Propeller, thickness of blades at hub..... 3¾ inches.
Propeller, helicoidal area..... 20 square feet.
Propeller, projected area..... 15.64 square feet.
Propeller, pitch ÷ diameter..... 1.4
Propeller, disc area..... 42.78 square feet.
Propeller, helicoidal area ÷ disc area..... .467
Propeller, projected area ÷ disc area..... .365
Propeller, immersion of center at mean draught..... 4 feet 3 inches.

CONDENSER AND PUMPS.

The condenser is of cast iron and forms part of the framing of the engine. The combined air and circulating pump is independent and located close to the condenser. It is of the Blake type and operated by one steam cylinder. There are two Blake vertical duplex feed pumps.

Condenser, length of tubes over all..... 8 feet 5½ inches.
Condenser, tubes, outside diameter..... ⅝ inch.
Condenser, number of tubes..... 541.
Condenser, cooling surface..... 731.68 square feet.
Condenser, cooling surface per I.H.P..... 1.46 square feet.
Air pump, diameter..... 12 inches.
Circulating pump, diameter..... 12 inches.
Steam cylinder, diameter..... 10 inches.
Combined pump, stroke..... 12 inches.
Combined pump, total length..... 8 feet 5 inches.
Combined pump, total height..... 4 feet 3⅞ inches.
Feed pumps, steam cylinders, diameter..... 5¼ inches.
Feed pumps, water cylinders, diameter..... 3½ inches.
Feed pumps, stroke..... 6 inches.

BOILER.

The boiler is of the Ward tubulous type, similar, in most respects, to those in use on the *Monterey*, but of a smaller size, being known as "P-30" with "Q" fire box. The general features of this boiler are sufficiently familiar to render a detailed description unnecessary. For the protection of the lower part of the central drum there is fitted around it, extending

from the grate bars about 20 inches up the drum, a fire-brick casing locked together by groove-and-tenon joints, securely laid in fire clay.

In addition to the usual precautions taken to prevent undue radiation from the casing, the uptake or cover of this boiler was made double and the intervening space filled with asbestos; the inner plate of the casing was also lined on the inside with asbestos board. While adding but slightly to the weights, this arrangement proved to be very efficacious while the boiler was under steam. Provision was also made for cleaning the tubes by steam.

The following are some of the principal dimensions and proportions of the boiler:

Number of tubes in height	30.
Number of concentric sections	8.
Number of tubes in concentric sections	480.
Inside diameter of tubes (normal)	1½ inches.
Weight per lineal foot	2.66 pounds.
Outside diameter of base moulding	11 feet 6 inches.
Outside diameter of fire box	11 feet 1 inch.
Outside diameter of casing	9 feet 10 inches.
Height of casing	8 feet 3 inches.
Diameter of drum (outside)	28 inches.
Height of drum	11 feet 3 inches.
Thickness of drum	$\frac{5}{16}$ inch.
Diameter of stop valve	5 inches.
Diameter and number of safety valves	2 of 4 inches.
Test pressure (hydrostatic)	300 pounds.
Steam pressure (working)	160 pounds.
Furnace doors (number)	4.
Heating surface, total	2,490 square feet.
Grate surface	74 square feet.
Ratio H.S. to G.S.	33.65 to 1.

WEIGHTS OF MACHINERY.

Propelling machinery, including all the auxiliary machinery, together with water in boilers, pipes and condenser	49.68 tons.
The most important detailed weights are:	
Main engine and condenser complete	36,250 pounds.
Combined air and circulating pump	2,800 pounds.
Thrust bearing	1,679 pounds.
Propeller	2,599 pounds.

H.P. cylinder	1,636 pounds.
I.P. cylinder	1,904 pounds.
L.P. cylinder	2,545 pounds.
Condenser	7,676 pounds.
Cast-iron columns	1,384 pounds.
Three connecting rods complete	885 pounds.
Crank shaft	3,525 pounds.
L.P. slide valve	300 pounds.
I.P. slide valve	159 pounds.
Thrust shaft	1,846 pounds.
Propeller shaft	1,960 pounds.
Weight of boiler in steaming condition	34,720 pounds.
Total fire-room weights including water in boiler, floor plates, fittings, etc.	46,821 pounds.

TRIAL.

The contract specified that "the machinery is to be operated at the dock at least twelve hours, and until it can be run continuously at full speed without heated journals, after which a trial trip is to be made until the engines will make a successful run of at least four consecutive hours, working off at 150 to 160 pounds pressure all the steam the boiler will make with clean fires, using free-steaming coal, to be selected by the inspector."

After a successful dock trial of twelve hours' duration, during which time the machinery worked excellently, the four hours' trial underweigh was begun. The start was from the contractors' wharf at Kaighn's Point, from which place she ran about two hours down the river, made the turn under full steam and ran back to the wharf. On the run down the steam pressure fluctuated considerably, owing to the inexperience of the firemen, but coming back no trouble was experienced, as the boiler steamed freely. In lieu of a blower a powerful steam jet is fitted in the base of the stack, but this only had to be resorted to at rare intervals to maintain the desired steam pressure. The speed was measured by a patent log, the accuracy of which had been tested by use on another revenue cutter.

The following data were taken as the average for the hour between 5 and 6 P. M., which represents what can be expected of the vessel under fair conditions. Owing to the fluctuation of the steam pressure, previously alluded to, the performance for the first two hours has not been included in the averages.

Speed, in knots per hour		13.1
Slip of propeller, per cent.		21.6
Revolutions of main engine per minute		160.2
Piston speed, in feet per minute		640.8
Steam pressure at boiler (per gauge)		160.25
Steam pressure at first receiver (absolute)		65.75
Steam pressure at second receiver (absolute)		20.8
Vacuum in condenser (inches of mercury)		24.5
Opening of throttle		Wide.
	Top.	*Bottom.*
Steam cut off in fraction of stroke from beginning... H.P.	.72	.66
I.P.	.72	.66
L.P.	.72	.69
Double strokes of air pump per minute		64.
Mean pressures in cylinders ... H.P.		72.7
I.P.		24.76
L.P.		9.02
I.H.P.... H.P. cylinder		198.
I.P. cylinder		167.2
L P. cylinder		144.
Total for main engine		509.2
Auxiliaries (estimated)		15.47
Total with auxiliaries		524.67.
Indicated thrust, pounds		8,495.
Indicated thrust per square foot of developed area (20 square feet) of propeller, pounds		424.7
Indicated thrust per square inch of thrust bearing, pounds		40.2
Cubic feet swept per minute by L.P. piston per I.H.P.		7.22
Square feet of cooling surface per I.H.P		1.46
Square feet of heating surface per I.H.P		4.89
I.H.P. per ton of boiler, water, fittings and all fire-room weights (20.9 tons)		25.07
I.H.P. per ton of propelling machinery, boiler and water (49.68 tons)		10.54

NOTES.

THE POSSIBILITIES OF SPEED ON THE ATLANTIC.

Under the above heading Prof. J. Harvard Biles, the eminent naval architect and designer of the *Paris* and the *New York*, has contributed an interesting article to the "North American Review."

He considers briefly the effect of making the termini of the ocean voyage at Halifax and Galway instead of those now used, and finds that it would reduce the distance about 800 miles, which for the *Paris* would save 500 tons of coal. This saving of weight in fuel consumed could be represented in a new steamer of the same dimensions by an addition to the motive power, and consequently to the speed. Less time would be taken to the voyage and less coal consumed in the aggregate, resulting finally in a gain of one sea mile per hour, equivalent to a reduction of seven hours on the voyage between New York and Queenstown. The Halifax and Galway trip would, under the circumstances, be accomplished in 4½ days, but, of course, there are objections to its adoption. Since the length cannot be shortened, and thus enable a reduction in the weight of fuel carried to be utilized for greater machinery power, the shipowner must look to other considerations to attain the same end. If the cargo-carrying capability of the Atlantic liner of to-day were reduced by 500 tons, and these 500 tons were replaced by additional motive power, the speed would be one knot more.

A reduction in weight or displacement may be looked for also in the substitution of nickel steel, which, it is pointed out, is 40 to 50 per cent. stronger than ordinary steel, and yet the disparity between the price of nickel steel and ordinary steel is not greater than between steel and iron when the former was first introduced. The adoption of nickel steel and the reduction of scantlings

would allow the machinery to be increased equivalent to another knot. In the matter of engines no immediate gain is anticipated, although Mr. Biles refers to the possibility of greater piston speeds, which is an element in the possibility of greater speeds.

More hope is based on the boiler experiments now being made. The great difficulty is the absence of data as to long steaming under the conditions obtaining on an Atlantic steamer; and in view of the great possibilities it is surprising that no extensive experiments have been made in an Atlantic vessel. It is admitted, for instance, that if the locomotive boiler as applied in torpedo-boats could be shown to give on prolonged voyages only two-thirds of its relative superiority on trial, its adoption would result of itself in a knot more speed. Again, there is the water-tube boiler; but all round there seems no disposition to make an experiment on a large scale in the merchant service.

Mr. Biles thinks that the development of the tubulous boiler promises to be more rapid in America than in Europe, and that the New World may lead the way.

The choice of fuel and the method of combustion are also important factors, for 5 per cent. gained in efficiency means nearly a quarter of a knot in speed in a 20-knot vessel. The principles of the combustion of coal are beginning to be better understood. Marine boilers, he says, have been known to give on land, under certain conditions, 50 per cent. more work per ton of boiler than the best marine boilers on board ship are at present giving. But the author regards petroleum as superior to coal in all respects, as experiments have shown that one ton of oil will do as much work as two tons of the best coal, and the saving of one-half of the fuel would, if the weight were added to the engines, give $1\frac{1}{2}$ knots more speed. The difficulty is the supply, and it is hinted that the use of oil for less important purposes might be prohibited. The importance to America of such a change in fuel is not underrated. Mr. Biles assumes that if nickel steel became cheap enough, and the lighter type of boiler, such as the locomotive type, became a certain success for continuous sea-going work, the speed may be increased by two knots above present speeds. If oil be the fuel used, the speed might be increased $3\frac{1}{2}$

knots, and the time record from Sandy Hook to Queenstown be 4 days 16 hours.

This, of course, is on the assumption that the dimensions of the vessel continue the same. But modifications in model add or detract from the speed. Mr. Biles says length is the most valuable addition which can be made with a view to increasing speed. He states further, that 50 feet added to the length of "one" of our best Atlantic liners, while adding nearly 10 per cent. to its gross money-earning capabilities, would not necessitate an addition of more than 4 per cent. to the engine power to attain the same speed. Draught is as potent an influence in regard to speed, but limitations have hitherto been necessary owing to harbor and dock accommodation. If the loading draught of some of our steamers were 30 feet instead of 26 feet, they could have been designed to have a speed of 1¼ knots more, presumably, although it is not stated, for the same power. The author says that there seems to be good reason to believe that the speed of 30 knots necessary to accomplish the trip in four days from New York to Southampton or Liverpool will be attained in another ten years. The vessel he suggests will be 1000 feet long, 100 feet wide, with a draught of water of 30 feet, with the structure of stronger steel than is at present adopted, with lightened boilers, and with oil or some equally light fuel instead of coal.

TAIL SHAFT PRESERVER.

Mr. T. Mudd, of the Central Marine Engine Works, West Hartlepool, has recently fitted to the propeller shafts of several steamers engined at these works, an arrangement for preventing the galvanic action which arises immediately at the ends of the brass liners when immersed in water, and the general corrosive action that proceeds along the middle part of the shaft between the liners when exposed to salt water in the stern tube, and which is aggravated by the churning action produced resulting in the water being largely mixed with atmospheric air. Mr. Mudd holds that the one great essential to be aimed at is keep-

ing the water away from the shaft. This has been attempted in several ways, such as by lengthening out the liners till they meet, and there brazing them together, but he believes it has never been effectually accomplished, and the covering of a shaft with brass all over is a very expensive expedient. Mr. Mudd's patent tail shaft preserver then consists simply of a tube or sleeve, made of first-class india-rubber, of such dimensions as to cling tightly to the shaft over the whole length between the liners, and for several inches up the inclined liners at its ends. For this purpose the liners are lengthened out about 6 inches more than is usual, and gradually tapered away to accommodate the elastic sleeve. This gentle tapering of the liners has another good effect, as it gradually diminishes the strength of the liner, and so overcomes the objection to a sudden change of strength where the liner finishes, and which, doubtless, in many cases aggravates the damage caused by galvanic action at that point. When the preserver is to be put on the shaft, the latter is thoroughly cleaned bright, and coated with a suitable cement, and by means of special apparatus of a simple character the sleeve is drawn over the end of the shaft until it is in its place, where it becomes embedded firmly in the cement, clinging so tightly as to make the accession of water beneath it quite impossible. When desired, the ends may be lashed with copper wire over wire gauze, and the lashings soldered together. To prevent any chance of the sleeve being damaged when the shaft is being pushed into its place in the tube, a false nut is provided which runs on the thread on the end of the shaft, the external diameter of which is precisely the same as the diameter of the brass liners, and which therefore holds up the point of the shaft as it passes through, preventing the elastic tube from being injured by the neck bush. This nut, of course, goes with the ship as part of the outfit.

PAINTING WOOD AND IRONWORK.

In a paper on "Painting Wood and Ironwork," recently read before the Engineers' Club of Philadelphia, Mr. Edward E.

Brown stated that a paint consisted of two portions, the pigment and the vehicle. Linseed oil was the vehicle most commonly used. It possessed the peculiar property of uniting with the oxygen of the air to form a tough leather-like compound called linoxin. This drying process took about thirty days to complete. It has been supposed that linoxin was impervious to air and moisture, but according to Dr. Dudley, chief chemist to the Pennsylvania railroad, this was not so, and during the drying process it had an oxidizing effect on the surface covered. Hence linseed oil was not as good a vehicle to use in painting ironwork as it was in the case of wood. With certain metallic bases linseed oil formed a soap. Thus with white lead a lead soap was formed, and an elastic skin of paint was thus produced over the surface to which it was applied. In time, by the action of water and the heat of the sun, the soap gradually decomposed and the paint began to chalk or flour of. Zinc white also formed a soap with linseed oil, which was harder and more brittle than that formed with white lead, and had a tendency to contract when drying and also to peel off in time. It had not the same tendency to chalk and flour that the white-lead soap had. It was best used as a final coat to an elastic undercoating of white lead. On account of this peculiar chemical activity of white lead and linseed oil, attempts had been made to substitute chemically inert substances for the white lead, but none of these had proved satisfactory, and probably there was a better chance of success of obtaining a satisfactory substitute for the linseed oil than for the white lead. Of inert pigments, lampblack was probably the best. It was unalterable save by fire and had great spreading properties. For ironwork, red-lead paint had long been considered as the best possible preservative, but it was necessary that the iron should be clean and absolutely dry before applying the paint. All the scale possible should be removed by stiff wire brushes, and the work should then be washed down with a pickle of very dilute acid, which should be thoroughly washed off before painting. Another method which had been suggested to clean the metal was to wash it with coal oil and remove this oil afterwards with benzine.

STEAM HAMMER *VS.* HYDRAULIC PRESS.

The relative efficiency of the hammer and the hydraulic press is a question which has been hotly discussed by experts. About four years ago some very interesting experiments were made at the Arbel forges at Rive-de-Gier in France, which failed in their immediate object, which was to establish a definite ratio between the weight of a hammer and the power of a press required to do the same work, but which nevertheless shed some light on this subject. The general conclusion reached was that forgings made under the hammer showed a finer grain and a greater degree of uniformity in texture than those made with the press. It was noted that while hammer forgings showed a better surface the press forgings had the greater density in the center. These experiments, while their general indications favored the steam hammer, were hardly carried far enough to be conclusive. It is not at all probable, however, that the steam hammer will be superseded, and for many classes of forgings it will always be indispensable.

NEW TYPE OF FERRULES IN THE BRITISH NAVY.

A trial has been made, at the suggestion of the Engineer-in-Chief of the Navy, on board the gun-boat *Seagull*, at Portsmouth, of a new device for preventing leakage in boiler tubes. Ferruling has enabled the engines of ships in the navy to develop their maximum power, but the ferrules require renewing, and they have the further disadvantage of rendering the process of sweeping tubes a matter of difficulty. The new invention consists in fitting the tubes at the furnace end with copper sleeves of the same diameter as the tubes themselves. One-half of the *Seagull's* boilers have been so fitted, and they were steamed for three hours, the other boilers not being lighted. The newly-treated boilers were tested to the extreme degree of 4.1 inches of air-pressure. This gave a mean steam pressure of 113 pounds, and with the high vacuum of 29 inches and 205½ revolutions the starboard engine developed 872 and the port engine 859 horses, resulting in a collective I.H.P. of 1,731. With all the fires alight at the official trial the power realized was 3,200. The speed of vessel was not taken. The trial was considered satisfactory.

TRAFFIC IN THE SUEZ CANAL.

A British government report has lately been issued giving a record of the traffic through the Suez Canal in past years, which shows that the number of vessels has tripled in eighteen years, and has about doubled in twelve years, while at the same time the average size of vessels has steadily increased, being now 2,167 tons, so that the gross tonnage of the vessels using the canal has multiplied fivefold in eighteen years, and has much more than doubled in ten years. The traffic receipts have increased in about the same ratio as the number of vessels, having tripled in eighteen years and about doubled in twelve years. The depression in the shipping trade during the past year is reflected in the statistics, for there is a falling off in all figures, although the totals do not, as a rule, fall under those of two years ago. The remarkable progress, indicative of the immense utility of the canal, is therefore but checked. Last year 3,559 vessels passed through the canal, against 4,207 in 1891 and 3,389 in 1890. The ratio of British vessels to the total shows a decrease. This is also the case in respect of tonnage, there being a decrease in net tonnage from 78.60 per cent. in 1891 to 75.55 per cent. last year. The total gross tonnage was 10,866,401 tons, against 12,217,986 tons in 1891, while the net tonnage shows a decrease of about a million tons. The annual receipts are a few thousand pounds short of 3 millions, whereas in the previous year they were 3½ millions. Last decade, however, the average was only about 2½ millions. Of the net tonnage of vessels using the canal, 93.5 per cent. were merchant vessels or mail steamers, the remainder being warships, &c. As to the number of passengers carried by the steamers, these also show a falling off, due to fewer homeward-bound civilians, &c., for fewer military men seem to have gone to the East and more have returned. The homeward passengers were as 83 to 100 outward last year, while in the previous year they were 85 to 103, so that the total is about 4,200 less, being 183,912. The mean duration of the passage for all vessels navigating the canal shows a considerable decrease, from 23 hours 31 minutes in 1891 to 21 hours 16 minutes

in 1892. In 1891 the percentage of vessels navigating by night was 88.2 per cent., while in 1892 it rose to 90 per cent., the number being 3,236 in 1892 as against 3,711 in 1891. The increase in the size of the vessels means greater draught, and now vessels drawing 25 feet 7 inches are allowed to pass through. Of these, 32 passed through during the past year. The number of deep-draught steamers is smaller, suggestive of less freight, but they bear a larger proportion to the total than in previous years, for the vessels drawing over 23 feet make 26.69 per cent. of the total, against 24.24 per cent. in the previous year.

DELTA WHITE ANTI-FRICTION METAL.

A new alloy under the above title is being introduced upon the market in England by the Delta Metal Co., limited, for use in bearings. Below is a copy of the results of tests made by Professor W. C. Unwin upon this new alloy. He states in his report that it works extremely well, and heats very little, even with high pressure on the bearing. It will be noticed from these results that the coefficient of friction is very low indeed, and that the temperature of the bearings is consequently very low, even under the heaviest load, and at the higher speed—viz: 315 revolutions per minute.

Mean revs. per min.	Mean pressure per square inch of journal surface in lbs.	Mean temperature in degrees Fahrenheit.	Mean moment of friction in inch-lbs.	Net pressure on one step, lbs.	Friction on one step at journal surface, lbs.	Coefficient of friction.
123	128.35	62.65	9.25	477.5	6.17	0.01292
	256.70	64 00	16.26	955.	10.84	0.01135
	385.05	65.75	24 23	1,432.5	16.15	0.01128
	513.40	67.70	40.87	1,910.	27.25	0.01428
315	128.35	73 80	12.00	477.5	8.00	0 01675
	256.70	76.20	17 25	955.	11.50	0.01204
	385.05	80.05	26 00	1,432 5	17.33	0.01210
	513.40	86.40	44.63	1,910.	29.75	0.01558

ALUMINIUM.

Mr. A. E. Hunt, of the Pittsburg Reduction Company, states that aluminium loses (permanently) much of its rigidity, and (temporarily) a very large proportion of its tensile strength, at a temperature of 400 degrees to 500 degrees Fahrenheit, becomes pasty at 1,000 degrees Fahrenheit, and melts at 1,300 degrees Fahrenheit. The longitudinal expansion of a 100-feet rod of aluminium is .00115 feet per degree Fahrenheit. Its conductivity for heat is, for hard-drawn wire, 38 per cent., and for annealed wire 38.9 per cent. of that of silver. For electricity its conductivity is 50 per cent. of that of silver. Thus, one yard of annealed aluminium wire of 98.5 per cent. purity, and of .0325 inch in diameter, at 14 degrees centigrade has a resistance of .05484 ohm. As regularly put upon the market the metal contains less than one-fifth of 1 per cent. of iron, and is free, therefore, from any appreciable magnetic polarity. By cold hammering, rolling, stamping, drawing, &c., the stiffness and hardness of the metal can be very much increased, as also by the addition of a few per cent. of alloy. Quite a small percentage of silver-chromium, manganese, wolfram or titanium is sufficient to distinctly improve the color of aluminium by approximating it to that of silver. For cold-rolling aluminium the number of passes is about the same as for the treatment of soft steel. There is little difficulty in reducing the metal by rolling alone to a sheet of one two-thousandth of an inch thickness. Aluminium is in the best condition for rolling, &c., at a temperature of from 200 degrees to 300 degrees Fahrenheit. The temperature of annealing is that at which a pine stick is charred by being drawn across the metal, or that at which a piece of iron appears just red in the dark. In soldering aluminium, successful results can be obtained with an alloy of that metal and zinc, with pure zinc, or even spelter or common soft solder, provided that a flux " which has just been covered by letters patent " be employed.

SHIPS.

UNITED STATES.

Maine.—Dock trial.—The machinery of this vessel, built by the Quintard Iron Works, has been completed for some time, but the hull work is delayed on account of non-delivery of armor, thus rendering it impossible to have a sea trial. As the final payment of the contractors for the machinery is contingent upon the sea trial, they have been kept out of a large sum of money It was finally agreed that half of this balance, some $75,000, should be paid them if a dock trial of the machinery showed entirely satisfactory working. With the designed steam pressure in the boilers, the engines were to develop a mean effective pressure of 30 pounds reduced to the L.P. cylinder, which is what will be necessary in the sea trial to secure the designed horse power.

The trials were made at the New York Navy Yard July 21st and 22d, one engine with half the boilers being used each day.

The engines are 35.5, 57 and 88 inches diameter of cylinder by 36 inches stroke, the piston rods being 6.25 inches diameter.

The air and circulating pumps are of the Blake combined pattern, driven by a compound engine. There are two vertical single-acting air pumps and one double-acting horizontal circulating pump; the former are 30 inches in diameter and the latter 31, the stroke being 18.5 inches. The steam cylinders are 12 and 24 inches diameter and 18.5 inches stroke.

The condensers have each 7,010 square feet of cooling surface

There are eight single-ended three-furnace boilers, 14 feet diameter and 10 feet long. The furnaces have an internal diameter of 42 inches. Each boiler has 71.73 square feet of grate and 2,376.92 square feet of heating surface, and as each trial was made with four boilers, the amounts in use were 286.92 and 9,507.68 square feet.

The following are the data of the trials:

		Starboard.	*Port.*
Date of trial		July 21.	July 22.
Duration of trial, hours		4.	4.
Steam pressure in boilers (per gauge), pounds		140.5	140.7
Steam pressure at engines (per gauge), pounds		138.2	139.0
Steam pressure at 1st receiver (absolute), pounds		65.1	67.4
Steam pressure at 2d receiver (absolute), pounds		29.1	35.3
Vacuum in condenser, inches		25.6	25.0
Revolutions main engine per minute		82.6	81.7
Double strokes air and circulating pump per minute		26.2	23.1
Mean pressures in cylinders,	H.P.	56.19	55.75
	I.P.	18.36	20.45
	L.P.	15.35	13.09
	Equivalent on L.P. piston	32.12	30.65
Indicated horse power,	H. P. cylinder	822.20	807.05
	I.P. cylinder	699 20	770.55
	L.P. cylinder	1,398 60	1,179 66
	Aggregate for the engine	2,920.00	2,757.26
	Air and circulating pumps	29.63	23.68
Coal (Pocahontas) per hour		5,992.	5,376.
Coal (Pocahontas) per hour per I.H. P		2.03	1.93
I.H.P. per square foot of grate surface		10.3	9.7

The trial was entirely successful in every way, all joints being tight and all bearings working cool.

Machias.—This vessel was tried with great success on June 10th over a course about 30 knots long in Long Island Sound, maintaining an average speed of nearly 15.5 knots for four hours. As the sister vessel, the *Castine*, will shortly be tried, it has been decided to postpone an elaborate notice of the trial until both vessels can be treated.

The *Machias* is a gunboat of about a thousand tons displacement, driven by twin-screw vertical engines of the usual type. The engines are in one compartment and have one condenser for both. The boilers are of the marine-locomotive type with flat-sided fire-boxes.

Length over all	198 feet 4 inches.
Length on L.W.L	190 feet 0 inches.
Beam at L.W.L	32 feet 0 inches.
Mean draught	12 feet 0.75 inches.
Immersed midship section, square feet	324.64

Displacement, tons	1,067.5
Cylinder diameters, inches	15.75, 22.5, 35.00
Stroke, inches	24.
Condensing surface, square feet	2,246.
Grate surface, square feet	120.
Heating surface, square feet	4,590.
Propeller, diameter and pitch	7 feet 8 inches; 8.86 feet.
Propeller, helicoidal area of one, square feet	15.44

		Starboard.		*Port.*
Steam pressure at boilers (gauge), pounds			163.2	
Steam pressure at engines (gauge), pounds		159.5		159.5
Steam pressure at first receiver (absolute)		91.2		106.2
Steam pressure at second receiver (absolute)		34.7		36.6
Vacuum in condenser, inches			25.7	
Revolutions per minute		218.55		223.53
Mean effective pressures,	H.P. cylinder	55.80		52.11
	I.P. cylinder	27.28		30.58
	L.P. cylinder	15.29		17.02
	Aggregate reduced to L.P. cylinder	37.70		40.16
Indicated horse power,	H.P. cylinder	259.57		288.25
	I.P. cylinder	313.70		287.50
	L.P. cylinder	430.38		387.87
	Aggregate	1,003.62		963.63
	Air pump		17.94	
	Circulating pump		15.73	
	Feed pump		19 75	
	Blowers		23.20	
	Other auxiliaries		2.30	
	Total, all machinery		2,046.17	
I.H.P. per square foot of G.S			17.05	
H.S. per I.H.P			2.25	
Speed per hour, knots			15.46	
Slip of propellers, mean, per cent			18.25	
$D^3 \times S^3 \div$ I.H.P. main engine			196.00	
Immersed midship section $\div S^3 \div$ I.H.P			609.00	

Massachusetts.—The Coast Line battle ship *Massachusetts* was launched at Cramp's June 10th. This vessel is an exact duplicate of the *Indiana*, of which a full description was given in the May JOURNAL, p. 492.

Minneapolis.—This vessel, a sister to the *Columbia*, so long known unofficially as "The Pirate," was launched at Cramp's August 12th. Complete descriptions of these vessels have been given on p. 513, vol. IV, of the JOURNAL, and, as the *Columbia*

will soon have her official trials, we shall postpone any further detailed description until the account of her trial trip.

Gunboat No. 7.—At its last session Congress authorized the construction of three light-draught gunboats adapted to river service. It was the intention, at first, to have the hulls of two of them composite and sheathed, and designs had been prepared with that idea, but, as the act of Congress said "steel gunboats," an opinion was requested from the Attorney General, who decided that they must be of steel. It seems somewhat ludicrous that the unanimous opinion of the Navy Department as to what was best in the design of ships should have to yield to a literal interpretation of an act doubtless framed hurriedly and probably without any intention of hampering the Department's action. The importance of sheathing our ships which are to make long cruises on foreign stations is undoubted, and has been repeatedly urged by Chief Constructor Hichborn. It is worth noting, too, that many foreign vessels of great size are now building which are to be sheathed.

Gunboat No. 7, while of light draught, is still of what may be called ordinary design, the constructors having reasonable latitude in their work. As will be noticed later this is not the case with the other two vessels.

The principal hull dimensions of *No. 7* are:

Length over all	233 feet 9 inches.
Length on L.W.L	220 feet.
Beam at L.W.L	36 feet.
Mean draught	11 feet.
Displacement	1,260 tons.
Coefficient of fineness	.506
Freeboard forward	17 feet 11 inches.
Freeboard aft	16 feet 2 inches.

The speed developed by the vessel, under conditions to be prescribed by the Navy Department, must not be less than an average of 14 knots per hour, maintained successfully for four consecutive hours, during which period the air pressure shall not exceed in the ash pits of the return fire-tubular boilers a pressure of 1 inch of water, and in the ash pits of the tubulous boilers a pressure of 2 inches of water, and for speed developed and main-

tained above 14 knots an hour the contractors shall receive a premium at the rate of $20,000 per knot, while, if the speed falls below 14 knots, a penalty at the same rate will be exacted. If the average speed falls below 13 knots, the vessel will be rejected.

The hull is to be of steel, not sheathed, with double bottom and close water-tight subdivision at the water line. The water-tight subdivision is to be so arranged that at least two skins must be pierced to admit water to the engine or fire rooms. The arrangements of decks above water is such as to provide ample freeboard and berthing accommodations.

There will be two military masts with light sail power. The boats must be stowed clear of the blast of the guns, but two life-boats must be so carried as to be rapidly lowered under all conditions of weather.

There will be a water-tight deck near the water line. Below this deck will be the propelling machinery, steering gear, magazines, shell rooms, and, in short, all the "vitals" of the vessel.

Protection of the hull against injury to the water-line region will be afforded by coal protection and suitable water-tight subdivision.

The battery will consist of eight 4-inch R. F. B. L. R., four 6-pounder R. F. Hotchkiss, two 1-pounder R. F. Hotchkiss, two gatlings. The 4-inch guns are to be mounted as follows: Four in the open on the spar deck, placed two forward and two aft, and four in sponsons on a covered gun deck, two on either broadside. The guns on the spar deck will be protected with shields attached to the gun carriages. Those on the gun deck will be protected by sponson armor 2¼ inches thick. Protection will be afforded the smaller guns by shields and extra side plating.

There will be one torpedo tube placed at the bow above the water line.

Evaporating and distilling apparatus will be fitted for fresh water supply; the allowance of water to be carried to be sufficient for fifteen days for officers and crew; and in addition sufficient to supply the boilers with fresh water for one day's steaming at full power (about 11 tons).

The total coal capacity will be 380 tons, of which 150 tons will be carried at normal displacement.

The electric lighting plant will consist of two units, each unit having an engine, dynamo and combination bed-plate, and each dynamo having a rated output of 100 amperes at 80 volts. The total weight of the whole electric installation, including all fittings, search lights, etc., will be about 10 tons.

ESTIMATED WEIGHTS.

Hull and fittings	705 tons.
Sponson armor	12 tons.
Armament, including ammunition, torpedo outfit, etc	74 tons.
Main and auxiliary machinery	161 tons.
Fresh water for boilers	11 tons.
Equipment, outfit and stores	148 tons.
Coal at normal displacement	150 tons.
Total weight, equal to normal displacement	1,261 tons.

The following boats will be carried: one 30-foot steam cutter; one 30-foot sailing launch; two 28-foot cutters; two 29-foot whale boats; one 18-foot dinghy.

The vessel has a covered gun deck, and the cabin and wardroom are on the after part of this deck, the wardroom country being T shaped, with the table in the cross of the T athwartship; eight of the wardroom staterooms are on this deck, the other four being on the berth deck below. Just forward of the wardroom, but separated by a bulkhead, are the pantry and bathrooms.

Just forward of this bulkhead is a space about 100 feet long for the battery and berthing space for the crew. Forward of this space are the refrigerating room, petty officers' bath-room, crew's water-closet, etc.

On the berth deck, abaft the four wardroom staterooms, are the cabin and wardroom storerooms, while forward of the wardroom are apartments like those for junior officers on most ships, but which will be here for the petty officers. Instead of stationary bunks they will be fitted with berths like those on a Pullman sleeper.

The compartment just forward of this will be mainly taken up by engine and boiler hatches, but some of the crew will find

berthing space. The next compartment will also be partly occupied by hatches, but will include coal bunkers, dynamo rooms and engineer's workshop. The remainder of the space on this deck will be for berthing the crew.

The hold, besides containing the machinery and coal bunkers, will have the magazines, store rooms, etc.

The complement will consist of 11 officers, 129 sailors and firemen, and 10 marines, making a total of 150.

The engines will be twin-screw, vertical, inverted-cylinder, direct-acting, quadruple-expansion, with cylinders 11, 17, 24 and 34 inches diameter and a piston stroke of 18 inches; designed for 1,750 indicated horse power with a piston speed of 900 feet.

The boilers are in two groups, the forward or main boilers being of the tubulous or sectional type and designed for a working pressure of 250 pounds; they contain about 100 square feet of grate and about 4,000 square feet of heating surface.

The after or auxiliary boilers are cylindrical return-tubular, two in number, and designed for a pressure of 160 pounds.

For full power steaming, the design is to run as a quadruple-expansion engine with steam from the main boilers to the high-pressure cylinder, steam from the auxiliary boilers going into the steam chest of the first intermediate cylinder. For steaming at low power, the engine is intended to run triple expansion, there being a disconnecting coupling by which the low-pressure cylinders can be thrown out, and exhaust pipes properly arranged to complete the design. The steam pipes of the two groups of boilers are so arranged that both may work at the same pressure (up to 160 pounds) on the main steam pipe to the high-pressure cylinders.

There is one condenser for each main engine, each with its own circulating pump, to which is attached a vertical auxiliary air pump, so that each condenser may be used in port for auxiliary purposes. The main air pumps are of the vertical-bucket type, one for each engine, each worked from the crosshead of the second intermediate cylinder.

The valves for the H.P. and first I.P. cylinders are of the piston type, and those for the second I.P. and the L.P. cylinders double-ported slides, all worked by Stephenson link motion.

The framing consists of wrought-steel columns supported on cast-steel bed plates, which rest upon the inner bottom plating.

The cylindrical boilers are each 7 feet 8 inches diameter and 9 feet 10 inches long, each with one corrugated furnace flue, 40 inches internal diameter, the total grate surface of these boilers being 42 and the total heating surface 1,358 square feet. They have been designed with special reference to cleaning and scaling, as it is the intention to have one of these boilers in use at all times, and, if necessary, to use salt feed in them only. For all ordinary passages, the fresh-water tanks built in the ship will be ample; but for long ones, it would be necessary to use the evaporator make-up and probably some salt feed, which, of course, must not be put in the tubulous boilers. The type of boilers and their size has been somewhat restricted in this vessel on account of her comparatively light draught, and from the fact that she has a double bottom.

Forced draft will be on the closed ash-pit system.

There are two main feed pumps in the engine room and one in each fire room, the latter, as well as the fire and bilge pump, being fitted to pump from the main drainage system, and all the pumps except the main feed as fire pumps.

There will be the usual evaporating, distilling and refrigerating machinery, turning engine, workshop engine, dynamo, ventilating, capstan and steering engines, ash hoist, and ash ejectors of the See pattern, the latter being the first to be fitted in any vessels of the Navy.

The weight of machinery, including water, auxiliaries and spares, is 172 tons.

In some respects, the machinery of this vessel is novel, and represents an original and admirable solution of the problem of making machinery that is amply powerful at top speed and economical at cruising speeds. Quadruple-expansion engines working with 250 pounds pressure certainly should give economy at full power, and it is to be noted that the three smaller cylinders have been specially arranged to be economical at a cruising speed of about 10 or 11 knots. It was for economy also that the air pumps are worked from the main engines, thus reducing the waste in this, the most powerful auxiliary.

The combination of the two sets of boilers at 250 and 160 pounds for full power is novel, but is really only an extension of the principle of exhausting the auxiliaries into the receivers.

In the same way the cylindrical boilers should be very efficient with a ratio of heating to grate surface of over 32. Under natural or light forced draft they should give a high economic evaporation.

It is probable that, when this vessel is completed, a series of extended tests will be made at various powers to determine just where the losses occur. At present the efficiency of the engine cannot, ordinarily, be separated from that of the boilers.

Gunboats 8 and 9.—These have been specially designed for river service, so that the draught is very limited. This has hampered the hull designers materially, so that, while the design is an admirable solution of the problem before them, the vessel cannot be expected to show as good a performance as if they had had greater freedom in the choice of dimensions.

The hull data are as follows:

Length over all	252 feet 0 inches.
Length on L.W. L.	250 feet 0 inches.
Beam at L.W. L.	40 feet 0 inches.
Mean draught	8 feet 10 inches.
Displacement	1,313 tons.
Coefficient of fineness	.517
Freeboard at bow	19 feet 9 inches.
Freeboard at stern	11 feet 2 inches.

The contract speed is 13 knots and the premiums and penalties are the same as for *No. 7*.

The provisions as to watertight subdivision, &c., are the same in general as in *No. 7*, but there will be only one military mast.

The battery is the same as for *No. 7*, but the arrangement is different. Two of the 4-inch guns will be mounted on the forecastle and the remainder on the gun deck. Those in the open will be protected by shields; the remainder by sponson armor 2¼ inches thick. The smaller guns will be protected by shields.

The total coal capacity will be 275 tons, of which 100 tons will be carried on the normal displacement.

The other matters are in general similar to those for *No. 7*, and the same complement of officers and crew will be carried.

ESTIMATED WEIGHTS.

	Tons.
Hull and fittings	771
Sponson armor	10
Armament, including guns, mounts and hoists	70
Equipment, outfit and stores	152
Coal at normal displacement	100
Main and auxiliary machinery	200
Fresh water for boilers	10
Total weight, equal to normal displacement	1,313

The boats carried will be the same as those for *No. 7*, except that the steam cutter and sailing launch will be 33 feet long.

The engines will be twin-screw, vertical, inverted-cylinder, direct-acting, triple-expansion, with cylinders 14½, 22 and 33¾ inches diameter, with a piston stroke of 18 inches; designed for 1,600 indicated horse power, with a piston speed of 850 feet per minute and a boiler pressure of 180 pounds.

The valves are of the piston type for the high and intermediate, and double-ported slide for the low-pressure cylinders, all worked by Stephenson link motion. The framing consists of wrought-steel columns supported on cast-steel bed plates, which rest directly upon the inner-bottom plating.

There is one main condenser common to both engines, and one main circulating pump, with connections for pumping from the main drainage system, the double bottom and the engine-room bilge. The main air pumps are vertical bucket pumps, one worked from each main engine. For use in port there is an auxiliary condenser, with a combined air and circulating pump large enough for all the auxiliary machinery that might be in use at any time.

For the same reasons that obtained in *Gunboat No. 7* the choice of boilers was restricted, and as these vessels are intended for use in China waters it was decided to put in boilers which could, if necessary, be fed with salt water and which could be readily scaled. Six return-tubular boilers of the same size as those designed for *No. 7* will be fitted. They will be

placed in two water-tight compartments, but with only one smoke pipe, and will contain 120 square feet of grate and 4,074 square feet of heating surface.

Forced draft will be on the closed fire-room system.

The same system of feeding and pumping is adopted as in *No. 7*, and the same auxiliary machinery is fitted.

The weight of machinery, including auxiliaries, water and spares, is 200 tons, which seems heavy for modern machinery. This is due to the boilers. As already stated, owing to the peculiar service for which these boats are intended, it was not considered advisable to fit tubulous boilers. Owing to the very limited draught and to the double bottom, the greatest diameter permissible for cylindrical boilers is 7 feet 8 inches, which compelled the use of six boilers.

As in the case of the hull, the design is an excellent solution of the problem before the designers, but, unless the limitations of the case are borne in mind, it may seem that the results are not quite up to the best recent practice.

Third-class Torpedo boats for U. S. S. Maine and U. S. S. Texas.— These are of the same general design, those of the *Maine* being the larger. There will be two of each.

The hull dimensions are as follows:

	Maine.	*Texas.*
Length over all	61′ 8″	50′
Length on load water line	58′ 6″	48′ 1½″
Beam at water line	9′ 5/16″	9′ 5/16″
Mean draught	2′ 2″	2′ 1½″
Displacement, tons	14.8	12.15
Coefficient of fineness	.455	.462
Weight of hull and fittings, pounds	13,785.	10,992.
Weight of equipment, pounds	219.	184.
Weight of ordnance, pounds	3,435.	3,460.
Weight of coal carried, pounds	2,240	1,680.
Expected speed, knots	18.	17.

The frames are 1 inch × 1 inch × 0.8 pounds, and the reverse frames ⅞ inch × ⅞ inch × 0.7 pounds. The bottom plating is 6¼ pounds, the sheer strakes 5 pounds, and elsewhere 3¾ pounds.

The battery will consist of a 1-pounder R. F. G. The *Maine's* boats will have a bow torpedo tube for an 18-inch Whitehead, while those of the *Texas* will have a deck training tube for the same size Whitehead.

The principal machinery data are as follows:

	Maine.	*Texas.*
Type of engine	Quadruple-expansion.	
Cylinder diameters in inches—H.P.	6.00	5.25
Cylinder diameters in inches—First I.P.	8.37	7.25
Cylinder diameters in inches—Second I.P.	11.75	10.00
Cylinder diameters in inches—L.P.	15.75	14.00
Stroke in inches	8.00	8.00
Condensing surface, square feet	150.	116.
Revolutions per minute	675.	675.
I.H.P.	200.	155.
Type of boiler	Tubulous.	
Steam pressure, pounds	250.	250.
Grate surface, square feet	12.	9.25
Heating surface, square feet	480.	372.
Weight of all machinery, including water, auxiliaries and spare parts, pounds	12,000.	9,900.

Each boat will have one quadruple-expansion, vertical engine, the H.P. cylinder being forward. To secure as perfect a balance as possible, the cranks of the H.P. and first I.P. will be opposite, as will those of the second I.P. and L.P., the two latter being at right angles to the two former. All the piston and connecting rods and crossheads will be of the same size, but the pistons of the H.P. and first I.P. will be of the same weight, and the same will be true of the second I.P. and L.P. The smaller piston of each pair will be thickened to secure equality of weight.

The shafts and working parts generally will be of forged open-hearth steel. The piston and connecting rods will be oil tempered. The shafting will be hollow. The framing will consist of forged-steel columns stayed by diagonal braces, so as to give a firm support to the slides. The engine bed plate will be of plate steel, supported on keelson plates built in the vessel and stiffened by an angle iron running fore-and-aft on each side of engine.

All of the cylinders will have piston valves except the L.P., which will have a double-ported slide. The H.P. and first I.P.

valve will be without rings, and that of the second I.P. will have a broad adjustable ring. The valves will be worked by three Stephenson links, the two forward ones being driven by the same link.

There will be two double-acting air pumps worked by eccentrics on the forward end of main shaft. These pumps are of a new type, designed by Passed Assistant Engineer Frank H. Bailey, U. S. N., one of which has been tested to 1,000 revolutions per minute, when, under unfavorable circumstances, it gave a vacuum of 20 inches. The circulating pump will be centrifugal and work independently. It will have a capacity to condense all the steam generated by the boiler when the main engines are not running. The circulation through the condenser, when the boat is in motion, will be caused by scoops fitted to the injection and outboard delivery.

Forced draft will be on the closed fire-room system.

The crank-shaft journals and pins are 3 inches in external diameter, with an axial hole $2\frac{1}{4}$ inches in diameter for the *Texas* boats, while in those for the *Maine* they will be $3\frac{1}{4}$ inches and $2\frac{1}{2}$ inches.

It is probable that at least two types of coil boilers will be used, and possibly a different one on each boat.

The hulls and machinery will be built in the navy yards, the *Maine's* boats at New York and those of the *Texas* at Norfolk.

ENGLAND.

Gibraltar.—Under the Naval Defence Act, Parliament authorized the construction of nine first-class protected cruisers amongst the seventy vessels of all types, included in what is now known as the Hamilton programme. These nine first-class cruisers are all alike in general design, excepting that four have been sheathed with wood and coppered, to enable them to keep the sea for long periods without requiring to dock. This renders them fit to go upon foreign commission. The *Gibraltar* belongs to this class, and may be accepted as a good representative.

The class is regarded favorably by naval critics, and Dr. W. H. White, C. B., Director of Naval Construction, has been de-

servedly complimented on the very satisfactory results of the trials, which have shown the accuracy of all the calculations. The design represents the happy medium between the conflicting desiderata in warships. It is accepted that the principal functions of a cruiser are to protect commerce, as a rule, single-handed, in which cases high speed and coal endurance, powerful offensive and effective defensive qualities are the important considerations. It is not necessary here to determine the relative importance of these factors, but to indicate to what extent they have been considered in the design of these vessels. While embodying many of the best features of the *Australia* class—two of which, the *Australia* and the *Galatea*, were built by Messrs. Napier—the armor belt on the water line has been departed from. Many question the efficiency of the belt, more especially when the ship is rolling in a heavy sea, or when with great waves the trough exposes the under-water hull to the enemy's fire; and if deeper belts cannot be adopted, owing to considerations of weight and speed, probably the best substitute is an increase in the thickness of the turtle-back armor deck which covers in all the machinery and vital parts of the ship. The *Gibraltar*, too, is, apart from this change, an advance alike in size, power and speed. We do not question the serviceable qualities in the *Australia* design, although, as a matter of interest, we indicate the essential differences. The machinery of the *Gibraltar* is about 1,100 tons, against 850 tons in the *Australia*. The newer vessel is 60 feet longer, and, although the total displacement is 1,750 tons more, allowing for the wood sheathing, the speed is two sea miles per hour greater, while the coal endurance is 2,000 knots longer at cruising speed. The *Gibraltar*, too, has the same primary armament and a few more machine guns.

Dealing for the present with the hull, we may first give the leading dimensions:

Length between perpendiculars	360 feet.
Breadth	61 feet.
Mean load draught	24 feet 9 inches.
Displacement	7,700 tons.
Weight of hull and fittings	4,040 tons.

The hull is constructed of Siemens-Martin steel, with large phosphor-bronze castings for the stem, stern post, rudder, shaft brackets, &c., the form of the stem constituting it a very formidable ram. The use of this bronze was necessary to obviate galvanic action which would result from the contiguity of the copper with steel, had it been used in the framing. The steel hull has been sheathed with teak planking, which was coppered at the dockyard, to enable the ship, as already indicated, to remain at sea for long periods without affecting her speed. The double bottom, which runs throughout, is constructed on the cellular bracket system, and is subdivided into a great number of watertight compartments, which afford security against damage by grounding, torpedo attacks, mines, &c. The protective deck, as already stated, extends from stem to stern, while the cylinders of the engines, which, being placed vertically, extend above this deck, are protected by 6-inch steel armor coaming, which is 5 feet 6 inches high and backed with teak; over the top, again, are heavy armored gratings. The thickness in the parts of the deck most exposed is 5 inches, and tapers to 2 inches forward and aft, while sloping toward the sides of the ship to below the water line. On the top of these sloping parts are coal bunkers, while other bunkers separate the boilers and engine rooms from the sides of the ship, and thus afford supplementary defence against shot and shell. The 5 inches thickness is made up of two $1\frac{1}{4}$-inch and one $2\frac{1}{2}$-inch plates. The deck beams are of angle-bulb section, and amidships they have a 9-inch vertical flange and $3\frac{1}{2}$-inch horizontal flange, while forward and aft the depth is 7 inches. There is a beam to every frame. These are spaced about 20 inches apart amidships, and there are gusset plates for extra attachment of beams and frames. There is one course, 4 inches in thickness, of teak sheathing. It is scarcely necessary to state that the interior, both below and above the protective deck, is minutely subdivided.

Above the protective deck there are the main and upper decks. They are of Dantzic selected red pine, the stringers being carried on T-bulbs 8 inches deep and 5 inches horizontal flange amidships, and 7 inches deep at the ends of ship. The

guns are mounted on these two decks. There are two 9.2-inch 22-ton breech loading guns. These are intended as bow and stern chasers, and are mounted on central pivot carriages, one immediately in front of the conning tower and navigating bridge, and the other aft a short distance from the stern. These guns can be fired on either broadside, besides commanding very large arcs of training before and abaft the beam, and as the vessel has an unusually high freeboard, they will dominate a great distance. The supports for these heavy guns are massive tubes about 26 inches in outside diameter, piercing the protective deck to the magazines. Through these tubes the ammunition is raised by a hoist. The mounting is supported from the bottom of the ship by a steel cylinder of about 9 feet in diameter. There are also at each side two shell hoists connecting with shell rooms below the protective deck. There are ten 6-inch quick-firing guns, three on each side of the upper deck, and two in each side in casemates on the main deck.

The port for the casemate was formed by the shell plating being cut away and the ends bent inwards about 3 feet 6 inches on each side. To these ends were attached the 6-inch shield curved outwards sufficiently to make it project about 2 feet outboard. The attachment of the casemate to the decks is a splendid job. The guns on these may fire parallel with the keel. On the bow and quarter on each side of the ship the hull has been pierced for the four quick-firing guns on the main deck. The guns are inclosed in converging walls of plating 2 inches thick, so that the men working them are protected, the ammunition being passed through a strong steel tube piercing the deck. These walls of steel revolve with the gun. There are twelve 6-pounder guns, distributed as follows: Two on the forward shelter deck, two on the after shelter deck, four on the upper deck, two on the main deck forward, and two aft. The auxiliary armament consists of five 3-pounder guns, and several machine guns. There are four fixed torpedo-launching tubes, two of which are submerged. The ship is also fitted with a conning tower forward constructed of 12-inch steel-faced armor, with a forged steel tube 8 inches thick, for carrying

the voice pipes, and leads down to the protective deck. From this tower the commanding officer can direct the vessel in action by means of telegraphs and voice pipes to the engines, guns, torpedoes, steering gear, &c. The ordinary conning station is above it, and consists of a spacious bridge with a large chart-house and appliances for the safe navigation of the ship.

There can be no question, therefore, of the protection or armament of the ship, while the speed obtained on the trial exceeded 20 knots; but on this point we shall have more to say in a future issue. Meanwhile it may be stated that amongst the auxiliary machinery are three complete sets of compressing machinery, three sets of combined engines and dynamos for electric lighting, two distilling machines capable of condensing 300 gallons of water per hour, two sets of boat-hoisting machinery, two steam ventilating fans, fans for the forced draft, direct-acting steering engines with gear for both steam and hand, and an engineers' workshop with its own engine and a very complete installation of tools. The coal supply under ordinary circumstances is 850 tons, which will enable the ship to steam continuously at a 10-knot speed over a radius of 10,000 knots, or 2,800 knots at a speed of 18 knots, but capacity is also provided for a supplementary quantity of coal, which is of the utmost importance in a vessel of this type.

The ship is ventilated both by natural and artificial means, the engine and boiler rooms and under the protective deck being ventilated by steam fans. Throughout she is lighted by electricity, having three sets of combined engines and dynamos, with about 500 incandescent lamps and four search lights, worked by machinery under cover. Amongst the other special fittings are the steam hoists with heavy derricks, for lifting the boats out and inboard from the beams, where they are carried above the upper deck. The steam steering gear is placed aft under the protective deck, with leads to the bridge and conning tower, and controls a large balanced rudder, which, with the twin screws, gives great power of manœuvring. The complement of officers and men will be from 500 to 600, for whom very commodious accommo-

dation has been provided on the main decks, &c. The officers' quarters are abaft the engines, and include a very large ward-room, with comfortable cabins, all with polished mahogany fittings; and in addition there is a complete suite of apartments for the admiral, consisting of a dining saloon, large writing-room, with a stern balcony opening off it, deck and sleeping cabins, pantry, &c. While many warships are not noticeable for their beauty, the *Gibraltar* has a very handsome and rakish appearance, being designed on fine lines for a high rate of speed, while her heavy armament and wide range of action will make her a very dangerous opponent.

The engines are of the triple-compound type, adopted in all navy ships since, on the recommendation of Dr. Kirk, they were first fitted by Messrs. Napier to the *Australia* and *Galatea*, with the result that practically for the same weight 9,205 indicated horse power was developed instead of the 7,500 indicated horse power originally intended. This adoption by the British Admiralty, however, was five months after Messrs. Napier had received orders from the Russian Navy authorities to fit engines of the same type to the ironclad *Sinope*,* three years' working of the now famous *Aberdeen* having established the efficiency of the principle. While the twin engines of the *Australia* and *Galatea* were horizontal, those of the *Gibraltar* are of the ordinary inverted vertical type. The high-pressure cylinder is in each engine 40 inches in diameter, the intermediate 59 inches and the low-pressure 88 inches in diameter, the stroke in each case being 51 inches. The high-pressure cylinders have piston valves, while the intermediate and low-pressure cylinders have slide valves. The cylinders are supported from the cast-steel bed plate by wrought iron columns, while to insure the necessary stiffness, diagonal stays have been fitted both longitudinally and transversely. This open design permits of ready access to all working parts, and, as the air pumps are suspended from the low-pressure cylinders and worked off the low-pressure pistons, there is no appearance of overcrowding about the starting platforms. The air pumps are single-acting, the cylinders being 24 inches in diameter and 51

* See "Engineering," vol. 1, page 81.

inches stroke. The condensers, which are constructed throughout of gun metal, are each supplied with condensing water from two centrifugal pumps, sufficient to discharge 1,000 tons of water per hour. The cooling surface in each condenser is 6,750 square feet, or 13,500 square feet in all. Steel has been largely used in the construction of the engines. The connecting rods are 8 feet centers, while the piston rods are 8¼ inches in diameter. The crank and propeller shafts are of forged steel and hollow, the external diameter being 15¾ inches and the internal diameter 8½ inches. The propellers are entirely of gun metal, each having three blades. The diameter is 16 feet, and the mean pitch 23 feet 3 inches.

The auxiliary machinery in the engine rooms consists of the usual Admiralty pattern of feed pumps, fire and bilge pumps, auxiliary condenser, air and circulating pumps, Weir's evaporator and two of Normandy's fresh-water condensers and pumps, capable of supplying 300 gallons of water per hour, while the engine rooms are thoroughly ventilated by means of two powerful fans placed above the armor gratings at the main deck. Convenient to the engine room is a large workshop, equipped with all the necessary machinery and tools.

There are four boilers, double-ended, the diameter being 16 feet, and the length 18 feet. The furnaces, which are 3 feet 7½ inches in diameter, are arranged with a common combustion chamber for each pair. The tubes are 6 feet 6 inches long by 2½ inches in external diameter. The heating surface of these four main boilers is 23,072 square inches, while the grate area is 696 square feet. There is, in addition, a single-ended boiler for supplying steam to the auxiliary machinery. It is 13 feet 6 inches in diameter by 8 feet 10 inches long, the heating surface being 1,682 square feet, and the grate area 55 square feet. While the stokeholds have been designed with a view to efficient working by means of natural draft, eight fans have been fitted on the protective deck for forced draft. The fans and fan engines are by Messrs. W. H. Allen & Co.

The machinery was designed to develop 10,000 horse power with natural draft for a speed of about 18½ knots, and 12,000

indicated horse power under forced draft for 20 knots, but the Admiralty decided that only one of the vessels of the class was meanwhile to be subjected to forced draft conditions.

On Friday morning, May 26, the *Gibraltar* left Spithead for a continuous eight hours' run at full speed in the English channel. All the conditions of the natural draft trial were most successfully accomplished, and the guaranteed power was far surpassed; 11,300 horse-power was easily attained for a considerable period. Indeed, it seemed quite possible that the forced draft power of 12,000 indicated horse power might be obtained under natural draft conditions, and thus dispense with the forced draft and its attendant troubles. The mean steam pressure throughout was 154 pounds with an air pressure of .15 of an inch, the fans merely running for ventilation purposes, and the average indicated horse-power developed during the eight hours was 10,553, being 553 in excess of the contract, with a coal consumption of 1.67 pounds per indicated horse power per hour, while the log showed that a distance of 164 knots had been traversed, giving a mean speed of 20.4 knots, a result greatly in excess of what was anticipated with natural draft.

The following are the tabulated results:

	Starboard.	*Port.*
Pressure of steam in boilers, pounds	154.	
Vacuum, inches	27.	
Revolutions per minute	106.	105.
Mean pressure, high	49.08	44.19
Mean pressure, intermediate	22.4	23.
Mean pressure, low	12.35	11.81
Indicated horse power, high	1,684 19	1,501.75
Indicated horse power, intermediate	1,672.05	1,700.64
Indicated horse power, low	2,051.83	1,942.99
Total indicated horse power	5,408.07	5,145.38
Collective indicated horse power	10,553.45	
Mean air pressure, inches	0.15	
Speed of vessel, knots	20.4	
Coal consumption per indicated horse power per hour, pounds.	1.67	

These results were obtained without a hitch of any kind; there was an abundant supply of steam, without any trace of priming. The absence of vibration in the engines was much

commented upon, and their speedy reversing and starting under full steam rendered manœuvring an easy matter.—*Engineering.*

Ramillies.—The new British line-of-battle ship *Ramillies* has completed her contract trials with most satisfactory results, and is now to be prepared for commission, when she will take her place with the Channel Squadron. This is the first of the battleships, built by contract under the Naval Defence Act, to be completed. Messrs. J. and G. Thomson, Limited, Clydebank, the builders and engineers, have not only excelled all previous performances of private firms, but have constructed the vessel within a period which compares most creditably with that taken by the Dockyards, even in the case of the *Royal Sovereign.* The credit is the greater when it is remembered that the armor plates were not delivered until several months after the stipulated time, and the construction of the vessel delayed, a consequence of the imperative demands of the Dockyards for plates from the same makers. The favorable mention of Messrs. Thomson for rapidity of production by their Lordships of the Admiralty in the Memorandum recently issued was therefore well merited. The *Ramillies* has been handed over two or three months before the expiration of the contract time; indeed, she will be flying her pennant as ready for action before delivery could have been insisted upon. Messrs. Thomson have also the credit associated with thorough compliance with the conditions of contract. It was originally intended that all the vessels should have machinery capable of developing 13,000 indicated horse power under forced draught conditions, but when the *Royal Sovereign* was tried it was found that during the third of the four hours' run the boilers, subjected to an air pressure of 1.6 inches according to water gauge, began to leak, and the trials were stopped, the results on the three hours' run being accepted as fulfilling conditions. The power indicated during the three hours was 13,312. It was then intimated to the various engineering firms responsible for the machinery of the other battleships of the class that the power to be developed in subsequent ships would be 11,000. The *Ramillies* succeeded in maintaining this, even under natural draft conditions.

Before entering into details as to the trial, it may be convenient to mention one or two of the leading features of the design of the machinery. The engines and boilers have already been illustrated and described in "Engineering,* but it may be repeated that the cylinders of each of the twin engines are 40 inches, 59 inches, and 88 inches in diameter respectively, by 51 inches stroke, and that they are entirely independent castings, connected by steel stay rods securely attached, while the column heads have strong cast-steel struts fitted in between them to increase their stability in case of ramming. The back columns are of cast steel, with separate hard cast-iron faces for the guides, and the front columns are of forged steel, thus giving a clear view from the starting platforms, which are in the wings of the ship. Each high-pressure cylinder has a piston valve, the intermediate one triple-ported slide valve, and the low-pressure cylinder two triple-ported slide valves, one forward and the other aft. A special type of relief ring is fitted at the back of these flat valves, and balance pistons are supplied to all the cylinders to reduce the strain on the valve gear as far as possible. The main condensers have a collective cooling surface of 14,700 square feet. Consistent with the general principle of economizing weight, adopted in the design of all warship engines, the casings and ends are entirely of naval brass plates riveted together. The steam is condensed outside the tubes, the water being circulated through them by 16½-inch Gwynne centrifugal pumps driven by an independent engine.

The boilers are single-ended, 15 feet 2 inches mean diameter by 9 feet 4 inches long, and each of the eight fitted into the ship has four furnaces of 3 feet 4 inches diameter. For the purpose of shutting off each combustion chamber from the others, and also for regulating the draft in each, separate dampers are fitted in the passage from each through the smoke-boxes, the gear being arranged to work the same conveniently from the stokehold floor. The total grate surface is 700 square feet, and the total heating surface 19,900 square feet. The total weight of the engines, boilers, &c., is about 1,150 tons.

* See "Engineering," vol. liv., page 197.

The vessel was in good trim when she left Portsmouth on April 25 on an eight hours' natural-draft run. The draught forward was 24 feet 3 inches and aft 26 feet 1 inch, which is rather less than the designed draught at the displacement of 14,150 tons. The vessel is 380 feet long, 75 feet beam, andhas a heavy belt of 18 inch armor, while the upper part of the hull is armored with 4-inch plates protecting the gunnery deck, where the ten 6-inch quick-firing and smaller machine guns are mounted. Into the details of design and construction it is not necessary here to enter, as the method of building the vessel was illustrated and described in detail in a previous volume.* The power was easily attained at the natural-draft trials. With the very low air pressure of .22 inch the mean power was 9,415 indicated horse power, with the engines making 96.6 revolutions. The detailed results are appended :

RESULTS OF EIGHT HOURS' NATURAL-DRAFT TRIALS OF H. M. S. *RAMILLIES.*

Steam in boilers, pounds	149.	
	Starboard.	*Port.*
Vacuum, inches	27.8	27.6
Revolutions per minute	96.7	96.6
Mean pressure, high, pounds	54.63	56.38
Mean pressure, intermediate, pounds	20.93	21.47
Mean pressure, low, pounds	10.36	9.82
Indicated horse power, high	1,710.	1,762.
Indicated horse power, intermediate	1,426.	1,461.
Indicated horse power, low	1,569.	1,487.
Total indicated horse power	4,705.	4,710.
Collective indicated horse power	9,415.	
Mean air pressure, inches	.22	
Speed of vessel, knots by patent log	16.75	
Coal consumption per indicated horse power per hour, pounds	1.7	

On Thursday, April 27, the vessel went out on her forced-draft trials, when with an air pressure (.35 inches) which is often exceeded under natural-draft conditions, the required power was far surpassed. The vessel had only left Portsmouth about half an hour when the trials commenced, and the eight 5 feet 6

* *Vide* "Engineering," vol. liv, page 412. See also *ibid*, vol. xl, page 433; vol. li, pages 251 and 283, and vol. liii, page 530.

inch fans were driven to give .63 inch of air pressure in the stokehold, according to the water gauge. The steam pressure was 148 pounds, and with a 28-inch vacuum the engines together developed 12,080 indicated horse-power. For an hour the ship ran under these conditions, developing with the full air pressure allowed under natural-draft conditions a horse power 3,000 in excess of natural-draft requirements, and, peculiarly enough, 1,000 in excess of forced-draft demands. The fans were then slowed down, and for the next hour and a half the 11,000 indicated horse power was exceeded with but ¼ inch pressure, while to the close of the trial the power was easily maintained with a pressure which never exceeded .4 inches. The mean of the four hours was but .35, and the indicated horse power was 11,549, the engines making 102½ revolutions. The detailed results follow:

RESULTS OF FOUR HOURS' FORCED-DRAFT TRIALS OF H. M. S. *RAMILLIES.*

Steam in boilers, pounds	150.5	
	Starboard.	*Port.*
Vacuum, inches	28.5	27.7
Revolutions per minute	102.7	102.56
Mean pressure, high, pounds	61.15	61.56
Mean pressure, intermediate, pounds	25.4	25.01
Mean pressure, low, pounds	12.17	11.65
Indicated horse power, high	2,033.	2,042.
Indicated horse power, intermediate	1,838.	1,805.
Indicated horse power, low	1,960.	1,871.
Total indicated horse power	5,831.	5,718.
Collective indicated horse power	11,549.	
Mean air pressure, inches	.35	
Speed of vessel, knots by patent log	17.25	
Coal consumption per indicated horse power per hour, pounds	2.17	

We have stated that the engines of the *Royal Sovereign* during the three hours she was under forced draft developed 13,312 indicated horse power, with an air pressure of 1.6 inches. The *Ramillies*, it will be seen, maintained 12,000 indicated horse power for an hour with a mean of .6 inch. That the power increases at a slower ratio than the draft applied is well known; but it is worth noting some of the results got with the *Ramillies*, not necessarily consecutive results. The first line of figures rep-

resents the steam pressure, which of course affects the power result, the second is the air pressure, and the third the power.

150	150	155	150	150	148	pounds.
.21	.23	.27	.39	.57	.63	inches.
11,129	11,436	11,609	11,764	11,930	12,080	I.H.P.

The plotting of these figures on a diagram seems to indicate the probable need of a similar air pressure to that required in the case of the *Royal Sovereign*, when developing over 13,000 indicated horse power (1.6 inches); but the boilers of the *Ramillies* were not subjected to this pressure. Certainly they passed through their trials easily and successfully, and on subsequent examination no ill effects were visible.

The speed, it will be seen, was 17.25 knots with 11,549 indicated horse power, while the designed speed was 17½ knots with 13,000 indicated horse power; but with 12,000 indicated horse power, which has been established by the *Ramillies* as a safe power, the former speed could be maintained, without any undue pressue. The trials were attended by Mr. Oram and Mr. Corner, chief engineer at Portsmouth Dockyard, on behalf of the Admiralty, while the contractors were represented by Messrs. James R. Thomson, George P. Thomson and J. G. Dunlop, who are to be congratulated on the result.—"Engineering."

Niger.—The new first-class gunboat *Niger*, built and engined by the Naval Construction and Armaments Company, was sub jected to another forced-draft trial of her machinery at the mouth of the Thames, on Saturday, May 20th. The machinery was tested on a run of three hours' duration, with very satisfactory results. The pressure of steam in the boilers was 148.3 pounds to the square inch, and, with the engines averaging 255.9 revolutions per minute, a mean of 3,773.3 horse power was registered, being 273.3 horse power in excess of the contract. The mean speed for the three hours' run was 19.3 knots.

Barham, Galatea.—The *Barham*, third-class cruiser, and the *Galatea*, belted cruiser of the first class, made commissioned trials of their machinery at Portsmouth on the 12th of May. The former, with 136 pounds of steam, 174 revolutions, and a

mean air pressure of 1.15 inches, developed 3,311 horse power, and attained a log speed of 16.2 knots; while the latter, with 129.7 pounds of steam, 98.5 revolutions, and an average air pressure of 0.2 inches, indicated 6,305 horse power, and realized a speed on the measured mile of 16.925 knots. Both trials were satisfactory, though in the case of the *Galatea* the trial was arrested by a rush of water through the hawseholes. The *Barham* left Spithead in the evening for service with the Mediterranean Squadron. The *Galatea*, after receiving the crew of the *Iron Duke*, will take up her station at Queensferry as coastguard ship.

Grafton.—The *Grafton* is the last completed of the nine first-class protected cruisers ordered to be built under the Naval Defence Act of 1889. She was designed by Dr. W. H. White, Director of Naval Construction, built by the Thames Iron Works and Shipbuilding Co., Blackwall, and engined by Messrs. Humphrys, Tennant & Co., Deptford. She was, for the purpose of more fully testing her capabilities, taken around from Sheerness to Plymouth to enable her trials to be made in deeper water. The run round from Sheerness having enabled everything to be in readiness, the vessel, on the 24th June, began her official trials.

A continuous eight-hours' full-power trial with natural draft to the boilers was first undergone, and gave the following mean results: Steam was maintained at a boiler pressure of 154 pounds per square inch, with .41 inch of air pressure in the stokeholds, and, with a vacuum of 27 inches, the engines attained a speed of 96 revolutions per minute, and developed a gross indicated power of 10,957 horses, giving the ship a speed by log of 19.5 knots, her draught at the time being 23 feet forward and 24 feet 3 inches aft. On Tuesday, June 27th, the weather being rather rough, the ship left Plymouth Sound at 8 a. m. for a four-hours' forced-draft full-power trial, of which the results were—that with 1.16 inches of air pressure in the stokeholds a good supply of steam was maintained at a boiler pressure of 148 pounds per square inch, the mean vacuum was 26.7 inches, the revolutions of the engines, which were remarkably uniform, reached a mean of 101.6 per minute, and the total I.H.P. developed by them was

13,484, the speed of the ship, taken at half-hour intervals by log, being 20.5 knots. The trials gave an excess in power developed by the engines over that contracted for of 957 I.H.P. for the natural draft, and 1,484 for the forced-draft trials.

The *Grafton* is a cruiser of the *Edgar* class. She is 360 feet long between perpendiculars, has a molded breadth of 60 feet, and a mean load draught of 23 feet 9 inches, at which her displacement is about 7,400 tons. She is fitted with two three-bladed gun-metal screw propellers 16 feet 9 inches diameter, each driven by a triple-expansion engine of the three-cylinder type, designed to develop a gross indicated power of 10,000 horses under natural draft and 12,000 horses under forced draft. Both the trials of her machinery under the conditions imposed are considered to have been highly successful.

Endymion.—The new first-class protected cruiser *Endymion*, 7,350 tons displacement and 12 guns, which has been built, engined and completed by Earle's Shipbuilding and Engineering Co., was taken on her official trial trip from Portsmouth Royal Dockyard on May 5th, when a continuous run at full speed for eight hours was made in the English Channel, and the following most satisfactory results were obtained:

Draught of water, forward	19 feet 3 inches.
Draught of water, aft	22 feet.
Steam in boilers	152 pounds.

ENGINES.

	Starboard.	*Port.*
Vacuum, inches	27.	27.1
Revolutions	99.6	99.3
Mean pressure, high-pressure cylinder	45.81	45.32
Mean pressure, medium cylinder	24.7	28.57
Mean pressure, low cylinder	13 15	12.4
Mean I.H.P., high-pressure cylinder	1,477.	1,457.
Mean I.H.P., medium cylinder	1,732.	1,999.
Mean I.H.P., low cylinder	2,052.	1,929.
	5,261.	5,385.
Total mean I.H.P.	10,646.	
Mean air pressure		0.17 inch.
Speed of vessel		20.96 knots.
Greatest revolutions on trial		102.
Indicated H.P.		10,868.

The speed was greatly in excess of what was anticipated, and the consumption of coal was also most satisfactory, being 1.6 pounds per indicated H.P. per hour.

There was not a hitch throughout the whole of the day, and the machinery worked smoothly and regularly, causing much gratification to all concerned. Immediately after the boilers were cooled down a thorough examination was made by the dockyard officials of all the shells and combustion chambers, including all the plain and stay tubes, stays, joints, seams and rivets, when it was found that not one of the plain tubes had leaked even slightly, and that in this case *no* cap ferrules were fitted, and the inspectors declared they had never examined a set of new boilers after trial in such good condition.

Crescent.—The engines for the first-class cruiser *Crescent* were built by Messrs. John Penn and Sons, Limited, Greenwich. The vessel was constructed at Portsmouth Dockyard, from the designs of Dr. W. H. White, C. B., Director of Naval Construction, and is one of the ships built under the Naval Defence Act. The principal dimensions are: Length, 360 feet; breadth, 60 feet 8 inches; displacement, 7,700 tons; mean draft, 24 feet 6½ inches. She belongs to the *Edgar* class.

The engines are designed for 12,000 indicated horse power, forced draft, and 10,000 indicated horse power for natural draft, and are of the triple-expansion, vertical, twin-screw type, having cylinders 40 inches, 59 inches, and 88 inches in diameter respectively, all with 51-inch stroke. The high-pressure cylinders are placed forward, and are fitted with piston valves. The intermediate and low-pressure slide valves are of the double valve flat type, and fitted with Church's relief arrangement. The cylinder covers, pistons and steam-chest doors are of cast-steel. The cylinders are carried on cast-iron columns at the back, and round forged-steel columns at the front, the motion bars being attached to the back columns. The bed plates are of cast steel strongly secured to bearers built in the ship. The piston and connecting rods are of Siemens-Martin steel, the piston rods being fitted with combination metallic packing. The crank shafts are hollow, of forged steel, in three separate pieces, the cranks being set 120 de-

grees apart. The surface condensers are made entirely of brass, the total cooling surface being 13,500 square feet. The circulating water is supplied by four 16-inch centrifugal pumps made by Messrs. Penn. The reversing gear is of the ordinary link-motion type, with solid bar links and adjustable working parts. Both steam and hand reversing gear are fitted. The air pumps are entirely of brass, and are worked from the low-pressure piston-rod crossheads. They deliver into a feed tank which overflows into the ship's fresh-water reserve tanks. Weir's evaporator and Normandy's distiller are fitted to each engine-room, making together 180 gallons of fresh water per hour, while the evaporators above can supply 400 gallons per hour to the auxiliary condensers; these last-named are two in number, and are made entirely of brass, and fitted to condense the exhaust steam from all the auxiliary engines on board. There is a Weir's feed engine in each engine room, and an auxiliary feed engine of Admiralty type in each boiler room.

Electric light machinery is supplied and fitted in each engine room. Air-compressing machinery is fitted in duplicate at each end of the vessel. Powerful boat-hoisting engines are supplied and fitted on the upper deck. The propeller shafting is hollow, of forged steel, 14¾ inches in diameter inboard, and 16 inches in diameter outside the ship.

The boilers are eight in number, of the marine return-tube type, 16 feet 1 inch in mean diameter and 9 feet 3 inches long, each containing four of Fox's corrugated furnaces 3 feet 8 inches in mean diameter. They are of Siemens-Martin steel throughout, and are designed for a working pressure of 155 pounds per square inch, and a proof pressure of 245 pounds per square inch. The heating surface is 25,248, and the grate area 855 square feet. The main steam pipes are 14 inches in diameter, and made of steel, while all copper pipes of 6 inches and over are wound with copper wire for greater security.

The preliminary trial of the machinery took place on the 16th of May, when, after a satisfactory run, the vessel was prepared for her official eight-hours' natural-draft trial, which was most successfully carried out on the 18th ult. Mr. Oram attended on

behalf of the Admiralty, and Mr. Rabbage represented the Dockyard; Mr. Wootton, chief inspector, the Steam Reserve; and Mr. J. P. Hall, the engine contractors. The indicated horse power developed was 10,370, without air pressure in the stokeholds, these being all wide open. The boiler pressure was 152 pounds; the vacuum, 26.6 inches, and the revolutions 97.9. The coal consumption is given as 1.8 pounds per I.H.P., and the speed, by patent log, as 18.6 knots.

Only the natural-draft trial was made, as it was determined by the Admiralty some months ago that the engines and boilers in this class of vessel (the first-class cruisers) should forego the forced-draft trials, although they are better prepared to fulfill the conditions that some of the other vessels built under the Naval Defence Act, having very large boilers, and machinery of such dimensions that the full power (12,000 indicated horse power) might be maintained with even less than ½ inch air pressure.

Alarm.—The trials of the first-class torpedo gunboat *Alarm*, the second of three vessels of this class constructed under the Naval Defence Act, from the designs of Dr. W. H. White, C. B., Director of Naval Construction, and built at Sheerness dockyard and engined by Messrs. John Penn & Sons, Limited, were most successfully carried out at the beginning of May.

The first of these vessels, the *Circe*, was tried some two months before, and the third ship, the *Leda*, is now fast approaching completion.

The official eight-hours' natural-draft trial of the *Alarm* took place off Sheerness on the 1st May, the mean I.H.P. developed being 2,593 and the maximum 2,819, as against the specified contract power of 2,500. The average I.H.P. for the first five hours was 2,750, but during the last three it was reduced to bring the mean down to about the contract. These powers were obtained with a mean air pressure in stokeholds of .8 of an inch, the contract allowing one inch.

The forced-draft full-power trial of three hours, during which the machinery is required to develop and maintain 3,500 I.H.P. with not more than 3 inches of air pressure, was made with great success on the 3d of May, the engines indicating a mean

of 3,884 H.P., with an average steam pressure in boilers of 148 pounds; vacuum, 27.5; revolutions, 262½. The mean air pressure in stokeholds was 2.17 inches, and the speed of the vessel 19.6 knots.

On examination of the boilers after the trials there was no evidence whatever of any ill effects from the application of the forced draft.

The following shows the powers for the six half hours as taken:

Half hours.	*Starboard.*	*Port.*	*Total I.H.P.*
1	1,924.1	1,958.8	3,882.9
2	1,913.5	2,054.2	3,967.7
3	1,909.4	2,014.3	3,923.7
4	1,923.0	1,956.9	3,879.9
5	1,830.4	1,923.2	3,753.6
6	1,921.5	1,975.0	3,896.5

Mean I.H.P. for the three hours, 3,884.

FRANCE.

The French Navy programme.—The French naval estimates for the year 1894 contemplate the laying down of no fewer than 32 new vessels of various types, viz: Three first-class battleships, five second-class cruisers, one third-class cruiser, one sea-going torpedo boat, five first-class torpedo boats, four second-class torpedo boats, nine torpedo launches, one second-class despatch vessel and three gunboats. The battleships which will be built, two in the dockyards and one by contract, will have a displacement of 11,000 tons and engines of 14,500 horse power, giving a speed of 18 knots. The armament of each will be four 11.8-inch, ten 5.5-inch, six 3.9-inch, sixteen 1.85-inch, ten 1.45-inch and eight revolving guns. The second-class cruisers, one of which will be built in a government yard and four by contract, are of two types. The first type, which is to include the vessels provisionally known as *E4*, *E5* and *E6*, will be of 3,990 tons displacement, 9,000 horse power and 19 knots speed, carrying four 6.2-inch, ten 3.9-inch, fourteen 1.85-inch and four 1.45-inch quick-firing guns. The second type, which is to include the vessels provisionally known as *G3* and *G4*, will be of 3,800 tons

displacement, 9,100 horse power and 19.25 knots speed, carrying six 6.2-inch, four 3.9-inch, eight 1.85-inch and twelve 1.45-inch quick-firing guns. These five vessels are improved *Chasseloup Laubats*. The third-class cruiser, which is to be built in a government yard, will be a modified *Galilée* of 2,300 tons displacement, 6,600 horse power and 20 knots speed, carrying four 5.5-inch, two 3.9-inch, eight 1.85-inch, four 1.45-inch quick-firing guns and four revolving cannon. The sea-going torpedo boat, which will probably be built by M. Normand, of Havre, will be a repetition of the *Forban*, which is now under construction, and will be of 3,260 horse power and 30 knots speed. She will measure 144 feet long. The first-class torpedo boats will be of 80 tons displacement, 1,350 horse power and 23.5 knots speed. The second-class torpedo boats will be of 53 tons displacement, 700 horse power and 20.5 knots speed. The torpedo launches, which are intended to be carried on the deck of the new torpedo-depot ship *Foudre*, will be 62 feet 4 inches long, displacing 14 tons, having engines of 210 horse power, and being capable of a speed of 16.3 knots. It is expected that they will be built at Creusot, where the plans have been prepared. The gunboats, of which particulars are not made public, are believed to be river gunboats for colonial service. The most noteworthy feature in the new French building programme is the enormous multiplication of guns in the larger craft. Each of the battleships, it may be noticed, will mount as many as fifty-four guns, of which no fewer than fifty will be quick-firing or machine guns. This number is far in excess of that carried by any British ship, and the determination of the French Government to mount so exceptional an armament seems to suggest that, great as are the already recognized advantages of the quick-firing gun, the weapon has a future even more important than is usually claimed for it.

Trêhouart.—The French ironclad *Trêhouart*, which was laid down in September, 1889, was launched from the Caudan yard, opposite Lorient, on the 16th of May. Originally designed as a coast-defence vessel of the *Jemmapes* type, the *Trêhouart* has since been so altered in character that henceforth she must be classed as a sea-going battleship. Among the alterations the

most important are the raising of the freeboard forward by 6½ feet, and, to compensate for the extra weight thus introduced, the substitution of 11.8 inch for 13.4-inch guns as the ship's main armament. The dimensions of the vessel are: Length, 283 feet 9 inches; beam, 58 feet 5 inches; depth, 42 feet 10 inches; extreme draught, 24 feet 4 inches. The displacement is 6,590 tons, and there will be two triple-expansion engines of 8,400 indicated horse power, which are calculated to give, with forced draft, a speed of 16 knots. The armament will consist of two 11.8-inch guns mounted single in turrets on the line of the keel, eight 3.9-inch quick-firing guns mounted in broadside, four 3-pounder quick-firing and ten 1-pounder quick-firing guns, and two torpedo ejectors. There is a single military mast placed forward of the two funnels. The armor includes a complete belt, with a maximum thickness of 18 inches, and a steel protective deck, with 12½-inch turrets and 14½-inch revolving cupolas or turret covers. The total cost of the ship is to be $2,850,000.

D'Entrecasteaux.—A new cruiser, the largest in the French Navy, is ordered to be built at La Seyne. She will be named the *D'Entrecasteaux*, being intended for service as flagship in distant seas, and will be sheathed and coppered. Her displacement will be 8,114 tons; her length at the waterline 393 feet 6 inches; her extreme breadth, 58 feet 5 inches; and her extreme draught, 29 feet 6 inches. She will have two vertical triple-expansion engines, with five cylindrical boilers, developing in all 14,000 H.P., and giving a speed of 19 knots. The normal bunker capacity is to be 650 tons; but it will be possible to carry 1,000 tons of coal. The protection consists of a 3.9-inch steel deck, with above it a great number of cellular compartments for coal and stores, the whole being covered by another steel deck three-quarters of an inch thick. The whole of the hull below the protection is occupied by the machinery, boilers, bunkers and magazines. Each of the heavier guns has its own separate ammunition hoist. These, and also all the auxiliary machinery, steering gear, internal lighting, loading and training engines, &c., will be electrical. The armament will consist of two 9.4-inch guns of 40 calibers; twelve 5.5-inch quick-fire, twelve

1.85-inch quick-fire and four 1.45-inch quick-fire guns, with two submerged and five above-water torpedo-tubes, two of the latter being in the bows. Each of the 9.4-inch guns will occupy a closed turret covered with 9.8-inch steel. Four of the 5.5-inch quick-fire guns will be on the spar-deck behind 2.8-inch hardened steel shields and the remaining eight upon the main deck in sponsons behind similar shields. She will cost $3,000,000, will be somewhat larger than the English first-class cruisers of the *Edgar* and *Crescent* classes, but a little smaller than those of the *Blenheim* type. She will also be exceeded in size by the Russian cruiser *Rurik*, but she will be a knot faster. In size she will most nearly approximate the *New York* of our own Navy.

RUSSIA.

Woewoda and *Possadnik*.—In consequence of the fine results achieved by the torpedo cruiser *Lieutenant Kasarsky*, built two years ago by Mr. Schichau, two new and similar cruisers, the *Woewoda* and *Possadnik*, were ordered by the Russian Government, and these were delivered in the spring of last year, fulfilling most satisfactorily all conditions imposed by contract. Below is given a selection of the results obtained. The principal dimensions and particulars of these boats are: Length, 58 meters (190.3 feet); breadth, 7.4 meters (24.28 feet); draught aft, 3.05 meters (10 feet).

The displacement on trial with full coal bunkers (90 tons), and all weights and equipments on board, was 400 tons. The engines consist of one set of triple expansion engines of 3,500 indicated horse power, supplied with steam from two locomotive boilers. Each boat has one fixed torpedo-launching tube and two movable ones. Her armament consists of several quick-firing and machine guns, and she is also provided with powerful electric search lights. The contract called for a speed of 21 knots on a three-hours' trial, but the mean speed actually attained on trial was 22.4 knots. The coal consumption on the forced-draft trial was 0.7 kilogramme (1.543 pounds) per indicated horse power per hour, and the results obtained during the progressive speed trials in this respect are given in the annexed table:

Duration of trial.	Revolutions per minute.	Results of trial.		Results as calculated by Mr. Afanassief's Formula.	
		Coal per hour.	Indicated horse power.	Coal per hour.	Indicated horse power.
Hours.		*Pounds.*		*Pounds.*	
1	220	4,766	3,600	4,766	3,600
1	200	3,813	2,798	3,632	2,700
2	180	2,445	2,012	2,722	1,970
$2\frac{1}{2}$	160	1,715	1,278	1,975	1,385
$4\frac{1}{2}$	120	957	534	960	584
3	80	404	234	444	218

At a speed of from 14 to 16 knots the coal on board will drive the ship a distance of 3,500 sea miles. The *Kasarsky*, it may be mentioned, has made the trip from Elbing round Europe to Nicolaief, and is counted now in the list of the Black Sea Fleet. The two new cruisers belong to the Baltic Fleet. Their sea-going qualities have also been tested during severe weather and have proved excellent.

MERCHANT STEAMERS.

Campania.—The Cunard steamer *Campania* has on her first Transatlantic voyage exceeded expectations, having in the homeward run excelled all previous steamship performances. Mr. Laing, of the Fairfield Company, who was on board, deemed it proper on the outward run to steam at an easy pace, so that the staff of engineers might the more readily become accustomed to the immense machinery; and on the home run they were drilled under something like the ordinary conditions of running of the engines. The result was a steadily increasing speed from the time of passing Sandy Hook until the arrival of the vessel on this side, the daily runs at noon on each having been 29 knots (for 115 minutes), 481, 490, 474, 517, 493, and for the remainder of the run 384. The complete distance of 2,899 nautical miles to Roche's Point was traversed in 5 days 17 hours 27 minutes which is 2½ hours better than the previous record journey made by the *New York* in August last. But on that occasion the latter steamer went the summer route, whereas the *Campania* adopted the southern course, to clear the Banks of Newfoundland at this season, and thus traveled a much greater distance in the less time. The result is therefore a speed of 21.15 knots by the *Campania*, against 20.10 knots by the *New York*. The sister ship, *Paris*, however, has, in the outward run, maintained 20.7 knots. The quickest homeward run by the pair of White Star vessels was made by the *Teutonic*, with a mean of rather under 20 knots. Nor was the *Campania* pressed. Only on the fourth day could the engines be said to approach the full contract power, 30,000 indicated horse power, and on that day the speed averaged the unprecedentedly high rate of 22.24 knots. This run, coupled with the fact that on another day there was a two-hours' delay

owing to a slight hitch in the steering gear, indicates that when the vessel goes on the shorter summer route of 2,800 nautical miles a month or two hence, she will easily accomplish the voyage in less than 5½ days. As it was, the passengers who embarked at New York on Saturday, May 16, were landed in Liverpool, for the first time on record, on Friday night, the 12th inst., some of them traveling to London at once. The distance between Queenstown and Liverpool, indeed, was covered at the rate of 22.48 knots, and but for the detention at Queenstown, landing the mails, the passengers might have got to London on Friday night also. The letters were delivered on Saturday morning in London, no time advantage being gained by disembarking them at Queenstown. The coal used on the homeward run, it may be added, was Pocahontas semi-bituminous coal, which contains, by analysis, 86½ per cent. of carbon.—"Engineering."

Fast passsage by the Campania.—The Cunard Royal Mail steamer *Campania*, which left Queenstown at 12.40 P. M. on June 18, arrived at Sandy Hook Lightship at 11.42 P. M. on Friday, after a passage of 5 days 15 hours 37 minutes, which is equal to an average of 21.1 knots. During the whole of the voyage the vessel went by the long southerly route. Her daily runs were as follows: 509, 548, 521, 494, 532, 260; total, 2,864 knots. It will be seen that on the second day the distance run was the best ever recorded for one day. The best previously recorded passage was the *Paris'*, 5 days, 14 hours 24 minutes, but this was over the summer route, a distance of 2,782 miles. As the *Campania* covered 82 miles more, her time by the short route would have been 5 days 12 hours and 13 minutes.

Paris.—The American Line doubtless feel elated at the performance of their magnificent steamship *Paris*, as just recorded. She already holds the record for the fastest transatlantic voyage—that between Queenstown and Sandy Hook, of 5 days 14 hours and 24 minutes. She has added to her laurels the fastest passage ever made between Southampton and Sandy Hook, on her last trip, the time being reduced to 6 days, 9 hours and 37 minutes, which is a matter of 2 hours and 7 minutes better

than the previous record, made by the *Fuerst Bismarck*, of 6 days 11 hours and 44 minutes.

The *Paris*' voyagers were thus able to leave London on Saturday, and on the succeeding Friday evening sleep comfortably in their homes or hotels in New York, an advance never before recorded, and which emphasizes the superior value of Southampton as a point of departure, as well as arrival. A great point is that the mails received from the *Paris* on Friday evening were distributed and delivered in this city the first thing on Saturday morning, thus enabling alert correspondents to catch the Saturday's foreign mail ships, and save fully four or five days' time in the transmission of their advices. These achievements mean a great deal to the people of both England and America, and in a greater degree than ever before shorten the commercial distance between both.

The days' runs of the *Paris* do not, it is worthy of remark, approach those which she has previously recorded, and this affords the best ground for the surmise that there yet awaits this incomparable Queen of the Seas still other triumphs in the transatlantic service. It is well within the probabilities to expect that the *Paris* will yet reduce the time between Southampton and Sandy Hook three or four hours, everything being favorable, and it is a fact that there are no ships in the trade that are at all likely to wrest from her the victory she has now won. It is gratifying to "Seaboard" to be able to record this victory for the fastest ship afloat, and that, too, under the American flag. It is another warning to Great Britain that her sea supremacy is assailed at last in a manner that is telling.

In quoting in full an article from the "Newcastle Daily Journal" last week we noted that the writer stated that the ink was scarcely dry upon the document transferring the *Paris* and *New York* to American registry before the blue ribbon of the North Atlantic passed to the *Campania*. So long as the *Paris* holds the record between the United States and Great Britain over the two greatest routes of travel, it is unnecessary to specifically contradict the assertions to the contrary, so abundantly frequent nowadays in the British press.—"Seaboard."

New White Star Steamer.—At Harland & Wolff's yard, Belfast, there was launched recently a twin-screw steamer named the *Gothic*, for the White Star line. This vessel is 490 feet long, 53 feet wide, and 37 feet 6 inches depth of hold, and her gross tonnage is about 7,500. "Engineering" of London says of her: "Although it is probable that the *Gothic* may make a few voyages in the New York service, as the bookings of the White Star line continue to be heavy for the autumn season, it is intended that she shall ultimately take her place with her predecessors, the *Ionic*, *Doric* and *Coptic*, and the steamers of the Shaw, Savill and Albion Company, the *Arawa* and *Tainui*, in the New Zealand trade, sailing from Plymouth each month, and calling at Teneriffe, Cape Town and Hobart outward, and Rio de Janeiro and Teneriffe homewards. The distance traversed on each round voyage exceeds 26,000 miles, and in thus, for the first time, introducing twin-screws into the New Zealand trade, the owners of the White Star line believe they are acquiring an additional element of safety. Accommodation has been arranged for 104 saloon passengers amidships. On the quarter-deck aft accommodation will be provided for 114 steerage passengers. In addition to ordinary coal and cargo space, this steamer will be fitted with two refrigerating machines having an insulated capacity for some 75,000 carcases of sheep. The *Gothic* will be the largest steamer, as well as the largest carrier in the Australian and New Zealand trades."

New Freight Steamers for the American Line.—As announced some time ago, the International Navigation Company of Philadelphia is having built on the Clyde two immense freight steamers, probably the largest in the world. The contract for one of the boats was placed with W. Denny & Bros., while the Thomsons were given the second boat to build, partly for the purpose of securing whatever advantages might be had from competition.

The boat being built by W. Denny & Bros. was launched July 4th and named *Southwark*. This magnificent steel steamer can well be claimed to be the largest deadweight carrier afloat. Her dimensions are: 480 feet by 57 feet by 40 feet, and she will carry 10,000 tons. The vessel is fitted with direct-acting, surface-

condensing, quadruple-expansion machinery, having four cylinders working on four cranks; cylinders, 25½ inches, 37½ inches, 52½ inches, 74 inches, with a stroke of 4 feet 6 inches, by Messrs. Denny & Co. The working pressure is 200 pounds, and the boilers are fitted with the new induced draft system of Messrs. Brown, and Serve tubes. By this means a large amount of power is got from boilers occupying a very small space. This steamer has been constructed in excess of the Bulkhead Committee report, and will be absolutely unsinkable with any two, and in some cases with any three, compartments open freely to the sea. As to the question of strength, this has been carefully considered, not only by the owners, the architect, Professor Biles, and the builders, but also by Lloyd's, to whose highest class she is built. While primarily intended for cargo-carrying purposes, she is also fitted for a limited number of passengers. Accommodation in the citadel is provided for 80 passengers in well-appointed state-rooms, while the dining room is situated on the top of the citadel deck. The 'tween decks are large, airy and well-lighted, and will give accommodation for 1,000 third-class passengers. Of course this steamer, like all first-class modern steamers, is fitted with electric light, refrigerating gear, and all the latest improvements both in the ship and engine departments.

Gloucester.—On June 10 there was launched from the marine department of the Maryland Steel Company the new 3,200-ton steel passenger and freight steamship *Gloucester* for the Merchants' and Miners' Transportation Company. The *Gloucester* will cost about $350,000, and is designed to resemble the steamer *Fairfax* in size and appointments. Her length is two feet greater than that of the *Fairfax*. The principal dimensions of the new boat are: Molded length, 272 feet; length over all 300 feet; molded breadth, 42 feet; depth from base line to top of third deck, 26 feet; to top of fourth deck, 34 feet. She will be registered at about 2,500 tons. The boat will be driven at a speed of about fifteen knots with triple-expansion engines of 28, 45 and 72 inches diameter of cylinders and 48 inches stroke of piston. Four boilers, each 13 feet 9 inches diameter and 11½ feet long,

having three furnaces, will supply steam at a working pressure of 165 pounds. The *Gloucester* will be fitted with an electric plant, steam steering engine and four hoisting engines. There will be accommodations for 140 passengers.

Valiant.—The new steel twin-screw yacht *Valiant*, built by Messrs. Laird Brothers for Mr. W. K. Vanderbilt, of New York, was launched on Wednesday, the 3d May, at Birkenhead. The principal dimensions of the vessel are: Length between perpendiculars, 310 feet; extreme beam, 39 feet 3 inches; depth, 25 feet 6 inches, and tonnage, about 2,400 tons. The hull is of steel, subdivided by watertight bulkheads, and fitted with a cellular bottom, arranged to carry water ballast. She will have two sets of triple-expansion engines, driving manganese bronze screws. They are intended to indicate about 4,500 horse power, which will insure on trial with moderate forced draft a speed of fully 17 knots, whilst under natural draft the vessel will steam 15 knots. The bunker capacity is about 650 tons, which will enable long ocean voyages to be made.

Car Ferry Sainte Marie.—The wonderful car ferry *Sainte Marie*, was completed by the Detroit Dry Dock Company for the Mackinac Transportation Company, consisting of the Michigan Central, the South Shore and the Grand Rapids and Indiana railways, early in June. She is by far the largest wooden boat on the lakes, and if we consider her beam, which is 5 feet more than that of any steel boat on the lakes, she lacks but little of being as large as the greatest of steel vessels on the lakes. Her engines are the most powerful on these waters, as they are expected to develop 4,000 horse power. This will drive the massive hull 15 miles an hour. The distance from St. Ignace to Mackinaw City being but 14 miles, the transfer of a whole train across the straits will occupy little more than an hour, giving as rapid ferry service as is known in the country.

The dimensions of hull and machinery are: Hull, 302 feet over all; 269½ feet keel; 50½ feet beam and 24 feet deep. Machinery: forward engine, compound, 28 and 52 inches by 40 inches; after engine, compound, 32 and 58 inches by 48 inches. Boilers, four, 11½ by 18 feet, carrying 120 pounds steam.

Propellers, forward, 10½ feet; after, 12 feet. The forward screw is for the purpose of breaking ice. In addition to the main engines, there are twenty auxiliary engines, among which is the Westinghouse engine that drives the dynamo for 350 incandescent lights. The construction is the heaviest known outside of war vessels. Over 2,000,000 feet of oak were used in this boat, and the hull is plated from keel to water line with steel. The system of double frames and stringer keelsons makes a double hull, and the holes cut through for the deadlights show that the inside planking, frames and outside planking have a total thickness of at least 18 inches in the part of the hull where deadlights are used.

An interesting feature of the boat is the steadying tanks. The weight of the cargo is raised nearly four feet above the main deck, through its being in cars, and this would cause the boat to roll heavily in a seaway but for the tanks between decks. There are two of these tanks and each has capacity for between 10,000 and 12,000 gallons of water, one being 37 feet and the other 34 feet long. These are filled about half full of water. When the boat rolls to port this water follows slowly and passes to the port side, and when the boat is again heeled to starboard there is a resistance, which tends to steady the motion, in the weight of nearly 10,000 gallons of water, which amounts to about 37.5 tons. The upper deck is devoted to crew's quarters, excepting two halls for passengers. The accommodations for the crew are roomier and more comfortable than in any other boat on the lakes. With the *St. Ignace* and *Sainte Marie* in service at the Straits, under the command of Commodore Boynton, nothing should go wrong at Mackinaw.—"Marine Review."

Mohawk.—One of the finest freight vessels to go into commission this season is the Western Transit Company's steamer *Mohawk*, launched recently at the Wyandotte yard of the Detroit Dry Dock Company, and whose machinery was built by the Dry Dock Engine Works, Detroit. This boat is built after the style of the successful package-freight steamers *Harlem* and *Hudson*, but is a much larger vessel. She is 310 feet over all, 42 feet beam and 24 feet deep, and will have capa-

city for about 2,300 gross tons of freight. The engines are of the triple-expansion type, with cylinders 27, 37 and 62 inches by 48-inch stroke. The boilers, two in number, are 11½ feet in diameter and 18 feet in length, and will be allowed 165 pounds of steam. In the construction of the *Mohawk*, as in all metal vessels built by the Detroit Dry Dock Company, all the plates are of open-hearth steel, and every piece is tested by the company's expert before it leaves the mill. This steamer is built at a cost of about $225,000.

S. S. Curry.—This steamer is of the same dimensions as Wheeler & Co.'s *Centurion*, for which Mark Hopkins of St. Clair, Mich., and Capt. John Mitchell of Cleveland, have agreed to pay $265,000. Neither owners nor builders are making any predictions as to the carrying capacity of this very big vessel, but it is probable that on a Sault canal draft of 14 feet 6 inches she will carry from Lake Superior, where all large craft are limited in cargo, 3,400 gross tons, and that if given 17 feet of water, as was the case with the *Maritana* last season, when that boat took 4,771 net tons from Escanaba to South Chicago, she would move 5,000 net tons without difficulty. A most important feature in her construction, aside from the location of engines in the center, is the extent of water ballast capacity, through which it is probable that the vessel when running without cargo may be made to draw 9 feet forward and 15 feet aft.

The principal dimension of the *S. S. Curry* are: Length over all, 378 feet 6 inches; length of keel, 360 feet; breadth, extreme, 45 feet 2⅜-inches; breadth, moulded, 45 feet; depth, moulded, 26 feet. For water ballast she has a cellular double bottom differing from the ordinary floor system employed in lake practice. The bottom extends fore and aft, and is 54 inches deep, with a capacity of 1,600 tons. The sheer strake is extra heavy, and doubled for the entire length of the vessel. Web frames are spaced 16 feet apart throughout the vessel, extending to the spar deck, and the deck beams are supported by three tiers of extra heavy I stanchions. This and other features of construction in the ship are in accordance with the rules of the American Ship Masters' Association. The American Ship Windlass Com-

pany, Providence, R. I., furnished the Providence steam windlass and capstan.

Steam at 170 pounds pressure will be furnished by three cylindrical boilers 12 feet 6 inches diameter and 12 feet 8 inches long. Each boiler has three 40-inch diameter furnaces, the total grate surface being 100 square feet, and the heating surface 6,500 square feet. The motive power will consist of triple-expansion engines, built in F. W. Wheeler & Co.'s shops, with cylinders 23, 37½ and 63 inches by 44 inches stroke. The valves are actuated by the ordinary Stephenson link motion. The high-pressure and intermediate-pressure cylinders have each a piston valve, and the low-pressure cylinder has a double-ported balanced slide valve. The links are of the double-bar type, and the motion is reversed by steam, the diameter of reversing cylinder being 12 inches. The bed plate is cast in one piece, and the framework consists of three straight cast-iron columns on the starboard side and three Y-shaped columns on the port side, having very large bearing surfaces for the slides, and through bolts are used throughout.—"Marine Review."

Whaleback built in England.—On the 15th of June there was launched from the yard of William Doxford & Sons, Limited, of Sunderland, a whaleback steamer, *No. 218*, which has been built on foreign account through Messrs. W. Johnston & Co., Limited, of Liverpool. This is the first vessel built in Great Britain of the American whaleback type under the McDougall patents. Her principal dimensions are 320 feet by 38 feet 2 inches by 26 feet; load draught, 19 feet, and she is intended to carry about 3,500 tons. She is fitted with triple-expansion engines, also by Messrs. Doxford. The cylinders are 23 inches, 37 inches and 60 inches in diameter by 42 inches stroke, and steam is supplied from large single-ended boilers. The hull generally is of the whaleback design, and above this are erected seven towers, forming supports on which are carried the winches, derricks, cabins, &c., the two towers over the machinery space being much larger than the others, and upon them and around the engine and boiler openings are built the whole of the cabins, which are 7 feet above the hull proper, and are supported at the

sides by large ventilating tubes which are carried down through the decks and into the engine and boiler room. The vessel has nine cargo hatchways, and, as usual in whaleback steamers, these are built without coamings, and are fitted with water-tight iron covers which are bolted down, leaving the whole of the upper portion of the vessel clear of obstructions other than the towers already referred to.

A phenomenally fast Steamer.—Feiseen, or flying arrow in the Japanese language, is the name given to the latest high-speed launch built by Gardner & Mosher, No. 1 Broadway, New York. She is intended solely for speed, and will certainly make over 30 miles an hour. In describing this boat the "Engineer" of New York says:

"Those who are not familiar with actual high-speed launches, as distinguished from alleged high-speed, or spurt-boats, so to call them, will be interested in a few facts concerning them. The *Feiseen* is 78 feet long by 9 feet 6 inches beam. That is, she is about nine times as long as she is wide. This gives her good stability for a vessel of her size, for there are many steam craft afloat which are ten, and a few even eleven times as long as they are wide. She is built of mahogany upon adequate frames, albeit they sound light to the reader. These frames are $1\frac{1}{4}$ by $1\frac{3}{4}$ inches and are spaced about 8 inches between centers.

"The hull consists of two thicknesses of light planking, both being of mahogany with cemented canvas between them, and is absolutely water tight without other aid than the copper fastenings, 30,000 in number. The deck is also composed of mahogany, and constructed in the same manner. The model is peculiar in that it resembles a canoe in midship section as nearly as any form. There is no keel, and the bow lines are all straight (and very handsome they make the *Feiseen* look in the water), while the stern is of peculiar construction. This begins at the extreme stern and extends forward to say 20 feet, where the screw shaft emerges from the hull. This method of construction prevents squatting, so-called, or burying at the stern, a fault common to all high-speed vessels of light draught, and also prevents the carrying (to some extent) of the water of replacement,

for the hull rides on top of it instead of dragging it along with her. The wave of replacement is the water which has been displaced at the bow and closes in at the stern of the vessel. In some high-speed torpedo boats this wave stands or stood on trial runs 3 and 4 feet above the stern and threatened to come on board momentarily. The stem of the *Feiseen* is covered with a bronze shoe which is brought to an actual knife edge, and a brass rail is carried all around her from stem to stern, giving the vessel a beautiful appearance. The boat has very little sheer, and nothing above deck except a roomy pilot house and a slight trunk over the saloon and engine room a few inches high. The saloon is twelve feet long, extending the full width of the boat, with a beautiful mahogany buffet and dresser, also toilet room, folding wash basin, with plenty of lockers and large store room.

"Naturally the interest of this boat to engineers and yacht owners centers upon the machinery, as it well may, for it is unique even for its kind. High-speed marine engines are quite common, and Mr. Mosher does not profess to be the originator of them, but he has been very successful with them, and this success has been obtained by courage tempered by common sense. The engines form the subject of a patent and are of the quadruple expansion-type, with cylinders 9½ inches, 13½ inches, 18 inches and 24 inches by 10 inches stroke, and the boiler is Mosher's patent water-tube marine boiler. All told the weight for engine and boiler is inside of 9,000 pounds. When we say that the engine is capable of exerting 600 indicated horse power and weighs under 3,600 pounds, we have stated extraordinary facts. This, it will be seen, is only six pounds per H.P. exerted, dead weight of engine and all that is on the bed plate, and is undoubtedly the lightest marine engine so far constructed for actual use in propelling a vessel. On first seeing the engine it strikes one as being almost naked, so free is it of the great multiplicity of parts one is accustomed to see, there being only two sets of valve gear for running all four of the engines. The valve gear is of the Marshall radial type, with some modifications introduced by Mr. Mosher, and the working parts—piston rod, crank shaft, columns, in fact, everything—is of forged steel of a high tensile strength.

"The crosshead and guide bar are of the slipper pattern, the former with babbited faces. The piston rod, connecting rod and crank shaft are all bored out, reducing the weights materially. Externally the piston rods are perhaps two inches diameter, but the removal of the center takes off a large part of the weight. The connecting-rod end on the crank pin has a peculiar box, it being in one forging with the rod, the babbit being run directly into it. The strap and boxes are also in one forging and are babbited. It is one feature of this engine that everything is as solid and with as few artificial fastenings as possible.

"Naturally with a piston and connecting rod vibrating 1,200 times a minute, or 20 times a second, as these do at high speed, there must be as few loose parts as there can be, and Mr. Mosher has brought them down to their lowest terms. The engine is fitted with piston valves throughout. All the valve-motion joints are bushed with bronze, and every refinement of the best engineering practice has been introduced throughout. The engine is oiled from a tank by the usual oil pipes, having independent adjustment and running to all the main parts in duplicate. The frame of the engine is very ingenious and novel, and plays an important part in the rigidity and success of so light an engine. It is composed of ten steel columns arranged in pairs, each pair being diagonally braced. These braces are so arranged that they shall act as tension rods, and so proportioned that they may be strained up to a tension far exceeding the maximum steam stress or thrust of the piston, thus absorbing the elasticity of the structure up to that point, so that no springing or movement of those parts can take place as long as the tension on them exceeds the working strain, thereby largely avoiding the vibration and illegitimate strains, such as would be caused were the parts to vibrate in harmony with the revolution of the engine. It certainly runs very steadily, even at this high rate of speed.

"The boiler has about 1,200 feet heating surface and 33 square feet grate surface. It has shown by an evaporative test, conducted by Prof. James E. Denton, Professor of Engineering at Stevens' Institute, considerably over 600 H.P. per hour with easy forced draft, 2½ inches air pressure, or about 20 H.P. per square foot of

grate surface. The boiler consists of two steam drums arranged over two water drums, placed on either side of the furnace. There are a great number of small generating tubes springing from each water drum and bending inward and upward forming an arch over the furnace, then bending outward where they enter the steam drums. Other tubes are so arranged as to form a wall around the furnace so that the gases of combustion pass throughout the length of the furnace, and then passing among the tubes again returning the length of the boiler to where they enter the stack. The form of the tubes allows of free expansion and there are no joints about the boiler that are exposed to the fire. The joints are all expanded in the usual way. Large return pipes support the steam drums at either end, and are never in contact with the fire, as they are outside of the casing. The boiler is essentially in two halves, either side of which may be run independently. There are no pumps attached to the main engine. Independent pumps of special duplex type are used. There being one air and two feed pumps. There is also a special engine for driving the fan that supplies air for the forced draft. The engine is capable of driving the fan 2,000 revolutions per minute, giving a plenum of air equal to eight or nine inches of water, while it is found that it need never exceed two or three inches to furnish all the steam required. There is also a surface condenser having about 600 square feet of cooling surface. The circulating water is supplied by the motion of the boat through the water, there being a lip or scoop extending from the bottom of the boat which forces the water through openings provided for that purpose."

The following account of a run of the *Feiseen* is from the New York "Tribune" of August 27, 1893:

"The *Feiseen*, owned by W. B. Cogswell, of Syracuse, started out from Tebo's pier at South Brooklyn and met the steamer *Monmouth*, of the Sandy Hook line, which is considered one of the fastest passenger boats in the harbor, off Bedloe's Island, on her 3·45 p. m. trip to the Highlands on Friday afternoon, and it was seen by every one on board that a race was at hand. The *Feiseen* was running under easy steam, but was rapidly gaining on the *Monmouth*, and when she had gained a lead of a mile the

Feiseen made a complete circuit and again came alongside of the *Monmouth*, and held that position for some time to allow the passengers on the *Monmouth* to get a good view of the boat until abreast of the quarantine ship at the lower boarding station, a distance of seven and one-quarter miles, according to the Government survey chart, remaining between this point and the *Monmouth's* pier at the Highlands. At this point the *Feiseen* again started ahead at a much higher rate of speed, which she sustained, reaching the *Monmouth's* pier, where she came to a dead stop exactly eight minutes before the stopping bell on the *Monmouth* was given for landing.

"From this it will be seen that the *Feiseen* had gained eight minutes on the *Monmouth* during the run of 7¼ miles. It is a well-known fact that the *Monmouth* makes the distance of 20⅝ miles from her pier at Rector street to the Highlands on an average of 20 miles an hour on her regular trips, and it is said that she has covered this distance in 53 minutes. The *Monmouth* ran the distance of 7¼ miles—that is, from the lower quarantine ship to her dock—in 21¾ minutes on this occasion.

"The *Feiseen* covered the same distance in 13¾ minutes, which is a speed of 31.6 miles an hour, and this against a flood tide throughout the run. This remarkable speed was never before reached by any boat in the world.

"The boat said to have held the record previous to this performance was the Russian torpedo boat *Adler*, built by Schichau, at Elbing, Prussia, with her record of 27.4 knots, equal to 31.55 statute miles, which was made over a single-mile run in slack water, while the *Feiseen* record was made over a seven and one-quarter mile course, against the tide. The *Adler* is a 152-foot boat, while the *Feiseen* is a little more than half her length, her dimensions being: length, 68 feet 9 inches; beam, 9 feet 8 inches; draught, 3 feet 1 inch. Her horse power is 600, and her displacement 13 tons. The engines are of the Mosher build, quadruple-expansion type. The hull and deck are planked with mahogany, as well as all the interior fittings. The main saloon is 12 feet long and the full width of the boat. She has a roomy pilot house, large cockpit aft, crew's quarters forward for six men, and a large ice chest, etc."

[Without any desire to reflect upon the wonderful performance of the *Feiseen*, which is truly phenomenal, the foregoing statement of the "Tribune" with regard to the circumstances of the *Adler's* trial requires correction. The *Adler's* record is the average of six runs over the measured knot, so that the speed is exact, and there is no correction or allowance to be made for tide. The runs were not made at slack water, as no reliable results can be predicated from runs made under such circumstances. The actual measured distance run was a little under seven miles, and the five turns while off the mile would increase the total distance run to twelve or fifteen statute miles.

We hope to be able, in a future number, to publish results of measured-mile performances, which, we understand, Mr. Mosher hopes to be able to carry out at an early date.—EDITOR.]

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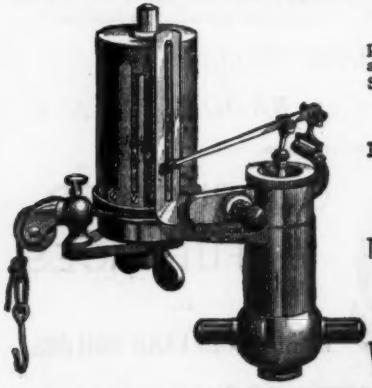

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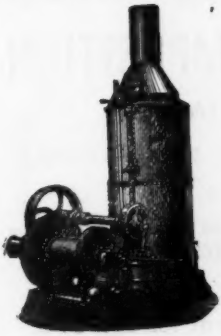

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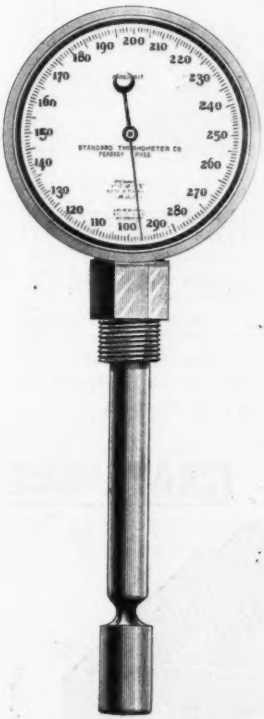

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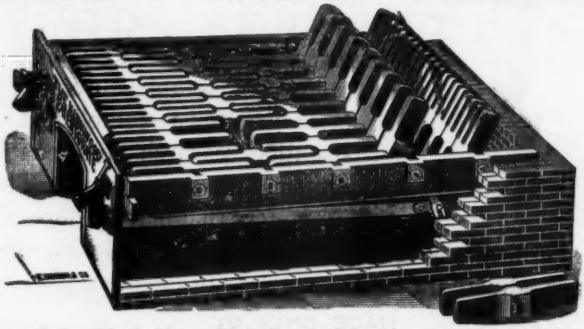

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